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STORAGE BATTERY INVENTION AND MANUFACTURE.

In this issue we print several articles referring to storage-battery construction and practice. The galvanic battery was the first apparatus invented in the subject of electrochemistry, and the manufacture of lead storage batteries was the first great electrochemical industry. Before the introduction of the more recent electrochemical processes, in which the electric current is the means for producing chemicals, it had long been known that chemical energy is the most efficient form of energy for storing electrical energy. The storage battery has now become a necessary accessory to electric lighting and railway plants, like dynamos and other electrical apparatus.

Stationary batteries for central station work represent at present 75 per cent. of all the storage batteries manufactured. For this purpose, the position of the lead cell seems secure. In the long series of years since the lead cell was introduced into practice, many inventors have contributed to its improvement, although the cell on the whole is the same as in the days of Planté and Faure. Battery design is now being standardized. For central station work, the manufacturer no longer aims to invent a new battery, but only to increase the reliability in practice and to diminisn the cost of the present lead cell.

In recent years, however, the progress of automobilism has set a new problem to the battery designer; that is, the invention of a battery of small weight and small size. The electric motor is conceded to be the ideal motor for an automobile, but the electric storage battery is far from being ideal for this purpose. The main trouble is, of course, that the lead cell is too heavy. Nevertheless, with the present batteries in the market, experience has conclusively proven that the electric automobile has a future.

Some exact data, given in this respect by Mr. Hugh Rodman in his recent American Electrochemical Society paper, are of great interest. The commercial life of lead plates in truck or cab service is about 15,000 to 20,000 miles for negatives, 12,000 miles for Planté positives and 6,000 miles for pasted positives. In other words, a 4 or 5-ton truck, running 20 miles per day for three hundred days in a year, requires new positive plates once in a year, or once in two years, according to the type of plate used. Cabs and lighter wagons have about the same life, with a capacity of 40 to 100 miles on one charge. Work done under these conditions—actual work reduced to dollars and cents—has shown that the electric wagon, as it is at present, gives better city service than can be gotten from gas, or steam, or horse.

Under these conditions, Mr. Rodman's conclusion is evidently justified, that if a better battery than the present lead cell was available, it would control practically all city traffic not on rails. This shows the importance of the problem. It can be solved either by devising an entirely new battery with

materials other than lead, or by improving the present lead cell. Mr. Edison has adopted the first means in his celebrated iron-nickel cell. His battery is so highly interesting in several respects that it is greatly to be regretted that authoritative information concerning the progress of its manufacture is not available. On the other hand, many skillful workers try to improve the lead cell by special means, and endeavor to adapt it to automobile practice. There is activity all around, and for this reason we trust that the descriptions of automobile batteries of American manufacturers, of which we print the first part in this issue, may be of interest to our readers. We may add that these descriptions are *ex parte* statements, based upon the information given to us from the manufacturers.

CALCIUM CARBIDE AND ACETYLENE.

On another page of this issue we print a review of the present conditions of the calcium carbide and acetylene industries. While the commercial crisis of these industries in Continental Europe is not yet over, we are glad to note that both of these industries show signs of healthful and steady growth and progress in this country.

These industries may be considered as a typical example of the progress made by electrochemistry in conquering Nature. They represent a case of storing up the energy which is given us from Nature in waterfalls, in the form of chemical energy (calcium carbide), which may be converted afterwards into light or mechanical energy (acetylene light and motors).

Calcium carbide is universally made by water-power, for the simple reason that the cost of power is a very important item in the total cost of the product, so that cheap power is essential for commercial success. Water-power always existed, but was not utilized until the development of hydroelectric stations began. The electric power, generated from water-power, can conveniently be converted into light and mechanical power, and there is the great advantage that, if only a transmission line is installed, the electric power may easily be transmitted to another place and there be utilized for lighting and power. But in these transmissions and conversions of energy there is one very important thing impossible: the energy cannot be stored up.

To store up energy efficiently, it is necessary to convert it first into chemical energy. This has long been recognized by the central station engineers when they installed storage batteries, to charge them at times of light load and to discharge them at times of full load. The efficiency of this system and its economical advantages are so well recognized that this arrangement is now generally used. Now, to charge a battery when the load in the station is light means simply to store up the surplus of electrical energy in form of chemical energy, and when the battery discharges, at times of full load, this stored-up energy becomes again free and available for light and power purposes. This conversion and reconversion of different forms of energy is necessarily accompanied by losses, nevertheless experience has proven beyond doubt that the total system is effective and economical.

What is done on a small scale by the storage batteries with the surplus of electrical energy in central stations is done on a much larger scale by the calcium carbide and acetylene industries with the energies of the waterfalls. The energy of the water is not the energy of the water *per se*, but that of the *falling* water; hence if it is not used or stored up just at the moment when the water falls down, the energy is lost. In hydroelectric power stations we have the means of converting the mechanical energy of the falling water into electrical energy, but, in order to store it up for future use, it is to be converted into chemical energy. This is done in the manufacture of calcium carbide in the electric furnace.

In order to make the whole process successful, it is, of course, necessary that the chemical compound which is produced in the furnace is of such a nature that the energy stored up in the same can easily be set free again and rendered available for useful purposes. This is decidedly the case with calcium carbide, as, by reaction with water, it yields acetylene. The advantages of the whole process are clearly evident. It is not astonishing that the progress of the calcium carbide industry has been rapid, but it is also evident that the progress of the calcium carbide industry must be necessarily associated with increase in the use of acetylene.

We print in this issue some remarks made by Mr. James Swinburne in his presidential address to the British Institution of Electrical Engineers on the real value of water-powers for electrometallurgical work. He thinks there is often an exaggerated value attached to water-powers, and that a water-power is useful only if it is at a place where it is wanted and needed commercially. This is exactly correct, but in his further remark, that as a rule water-power is not where it is wanted industrially, Mr. Swinburne seems to have the conditions of England merely in view. The conditions in this country are different. Niagara Falls, Massena and Sault Ste. Marie are near the great waterways and railways; transportation is cheap. These plants are commercially in touch with the commercial centers of this country. It is just for this reason that the prospects of a healthful and rapid development of electrochemical industries at those places are bright. The development of Niagara Falls as an industrial center has been an object lesson in this respect, and we trust the other great American water-power plants will equally become centers of electrochemical activity.

FREE IONS.

When the theory of electrolytic dissociation was first put forward, it was not received with open arms by the chemical public at large; it was rather ridiculed and laughed at. In return, the promoters of this theory emphasized their standpoint with stubbornness and boldness. This explains some rather unfortunate terms used in the nomenclature of the theory. In order to emphasize that a salt when dissolved in water is in a different molecular condition than before it was dissolved, and that its two kinds of ions are in some respects independent of each other, the term dissociation was borrowed from the chemistry of gases and the term "free ions" was coined. While it was pointed out that electrolytic dissociation is essentially different from ordinary chemical dissociation, yet the old term was adopted for a new conception. The meaning of the ionic theory is now better understood, and no

serious misunderstandings may be feared at the present time from the use of the term electrolytic dissociation. Nevertheless it may be worth while to analyze briefly the ideas underlying the adoption of this term, and to show in which respects ions are "free" from the point of view of the dissociation theory.

An absolutely indisputable way of getting at the answer, and a way which excludes any misunderstanding, is to consider the differential equations, assumed by the theory of electrolytic dissociation, to govern the whole ionic mechanism. These equations, as given by Nernst (and later, in an elegant mathematical form, by Planck), are the foundation of his theories of diffusion and of concentration cells, and state exactly the sense of the theory, and there can be no dispute about their meaning.

Two different kinds of forces are assumed to exist in the interior of an electrolytic solution—osmotic forces and electrostatic forces. The osmotic forces are due to concentration differences existing in the solution. Differences of concentration at different places in the solution produce different osmotic pressures, and they tend to equalize, just as would be the case in the interior of a gas if different pressures should exist at different places, the law of the osmotic pressure and the law of the gas pressure being identical. The second kind of forces—the electrostatic forces—are due to the electrostatic charges of the ions. Each monovalent gram ion has a charge of 96,540 positive or negative coulombs, and the attractions and repulsions between the different ions are assumed to follow strictly the ordinary laws of electrostatics. If we consider any point in the interior of an electrolyte, then there is a certain force acting there, and this force is the resultant of the osmotic force and the electrostatic force existing at this point.

Now, let this total force be given at any point of the solution, and also the numbers of different kinds of ions at that point, what will happen? The theory assumes that all the positive ions will move in one direction of the line of force, and all the negative ions in the other direction. The theory further assumes that each ion tends to travel independently of the others, the speed of each ion being simply its "mobility" (Kohlrausch) multiplied by the acting force at that place. As the mobilities of the different kinds of ions are different, they would travel with different speeds, and the so far independent of each other. But nevertheless—and this is a very important point, clearly brought out in the equations of the theory—there is in any given space inside of a homogeneous solution exactly the same number of positive and of negative ions. At no space inside the solution is there free electricity.

We know there is a certain energy required for decomposing an electrolyte, say hydrochloric acid, between inert electrodes. In the sense of the theory of electrolytic dissociation, this energy corresponds to the change of the H and Cl ions into atoms. This emphasizes the fundamental difference which the theory makes between ions and atoms.

To sum up, the theory assumes a "dissociation" into ions, not atoms. The characteristic feature of each gram ion of the valency n is that it is charged with $n \times 96{,}540$ coulombs. Each kind of ion has a characteristic mobility, determining the speed at which it travels under a given force. Finally, a certain energy corresponds to the change of an atom to an ion, and this energy, when measured in calories, is called the ionization heat. It is thus fairly clear that this electrolytic dissociation is essentially different from chemical dissociation.

It is therefore a pity that the promoters of this theory did not propose the concise and clear term "ionization," instead of the ambiguous term "electrolytic dissociation." Many misunderstandings would then have been avoided. Concerning the justification of the term "free ions," it all depends on what we mean by "free."

While the whole idea of the dissociation theory, when first proposed, was decidedly novel, yet the several assumptions made concerning the properties of the ions were not so. That the ions travel independently with different speeds has been known from the time of the investigations of Hittorf and Kohlrausch. Views approaching the hypothesis of dissociation had been expressed by Clausius. That each ion carries a certain charge had also been known for a long time. To quote only two authorities: "If we adopt the atomic theory or phraseology, then the atoms of bodies which are equivalent to each other in their ordinary chemical action have equal quantities of electricity naturally associated with them" (Faraday); and, "The same definite quantity of either positive or negative electricity moves always with each univalent ion, or with every unit of affinity of a multivalent ion" (Helmholtz, 1881). Nevertheless Arrhenius' famous paper was decidedly original, because he suggested distinct methods for determining the exact number of the ionized molecules and because by his theory he endeavored to save the general validity of Van't Hoff's application of the gas laws to solutions. We do not belittle his work in the least if we must admit that, in the light of more recent investigations, it becomes quite questionable whether Arrhenius' methods for determining the number of ionized molecules are really correct.

It is even quite doubtful whether the whole conception of the condition of the ionized solution is really so simple as the theory assumes. True, the theory is claimed to be strictly correct only for infinitely dilute solutions, and difficulties resulted generally from experiments with more concentrated solutions, so that they should not be used as an argument against the theory. That the theory deals with an ideal case, *i. e.*, infinite dilution, is absolutely no reason to belittle it. It is the same thing with the theory of alternating-current phenomena, which starts from the assumption of sinusoidal waves which scarcely exist in practice.

Finally, we may say that some of the difficulties in the conception of ions will disappear when the more recent assumption of an ion being a compound of an atom with an electron becomes more general. Many points which are otherwise not clear are thus explained. The ionization heat is simply the formation heat of an ion from the atom and the electron. Above all, the theory becomes so simple that it recommends itself to the practical man. Every chemist uses in his calculations the conceptions of atoms and molecules, because they simplify the conceptions and calculations. For exactly the same reasons the "atomic theory of electricity"—that is, the electron theory—recommends itself to the practical electrochemical engineer.

WESTON INSTRUMENT PATENT DECISION.

While we are going to press we are informed that Judge Coxe, of the United States Circuit Court of the Southern District of New York, has handed down a sweeping decision in an infringement suit instituted by the Weston Electrical Instrument Co. He sustains two Weston patents for alternating-current instruments in all points, one being a re-issue patent, dated June 28, 1892, the date of the original application being January 18, 1890, and the other, a patent subsidiary to this, dated March 8, 1892.

JAMES SWINBURNE ON WATER-POWER AND CARBON CELLS.

Our English contemporaries just begin to reprint Mr. James Swinburne's presidential address to the (British) Institution of Electrical Engineers. The London *Electrician* editorially characterizes it as "one of the finest presidential addresses that it has been the good fortune of the Institution to listen to." To our readers Mr. Swinburne's remarks on the utilization of water-power and on the prospects of carbon cells may be of special interest.

Mr. Swinburne thinks that an exaggerated value is vulgarly attached to water-powers. "As a rule water-power is not where it is wanted industrially. In the nature of things, water-powers are generally in hilly countries, and are seldom near the sea. The result is that a water-power as a rule cannot command the same price as steam or gas, because it is not where it is wanted. The idea in starting many of the water-power stations also was that works which needed power would come and settle near. As a matter of fact, the cost of power is a much smaller item in most industries than is generally supposed, and it does not pay to start a works in an otherwise not perfectly suitable locality simply for the sake of cheap water-power. . . . It may be said that in electrometallurgical processes the whole cost is practically the electrical energy, and so carbides, aluminum and electrolytic soda and chlorate of potash will be made at water-powers. Even this, however, is misleading. Carbides and aluminum are generally made at waterfalls, and chlorate nearly always is. Electrolytic soda and bleach are made at water-powers, but are also made extensively by steam-driven plants. Against the cheaper power, we have to put extra carriage for materials and for coal, which is often needed in addition; and extra carriage for finished products, and very often extra cost of labor, as labor is often dear and bad in water-power districts. Let us take, as an example, calcium carbide. The general idea is that the electrical energy is practically the whole cost of the carbide, but, taking present practice and the price of carbide at £13 10s. a ton, doubling the cost of power, instead of nearly doubling the price of the carbide, only increases it a little more than 10 per cent. Difference in local cost of coke, lime and labor, coupled with cost of carriage, may thus easily be of more importance than cheap power, even in such a case as calcium carbide, which is an electrical furnace product in which, at first sight, the power seems to be the main element of cost. In the case of electrolytic caustic and bleach, for 1 ton of caustic and the corresponding bleaching powder, the electrical energy, taken at £2 10s. per kilowatt year, a low water-power cost, comes to about 17s. 6d. The caustic and bleach sell for about £20, according to a varying market. Doubling the price of power, therefore, increases the price some 5 per cent. It may thus easily pay to use much more expensive power if the other conditions are more favorable. Steam-power, for instance, will cost three or three and a half times as much, and yet it pays to make electrolytic caustic and bleach in England where the other conditions are all favorable. It is not, therefore, the want of water-power that has kept the electrolytic industry back in this country. For a water-power to be really valuable, it should be near a source of material on the sea, and should have a great head of water, so that the capital cost of development is small. Such a water-power is very valuable—to the landlord."

"A blast furnace is more valuable than a water-power. There are plenty in England, but the owners, who have been wasting the gas up to now, will not give it away; they will want rent, so that it will only just pay to use his gas rather than make it. The electrical industry thus does not gain, but the iron masters do."

Mr. Swinburne's remarks on carbon cells are as follows:

"For many years 'electrical energy direct from coal' has been the dream of the electrochemist. That is to say, he has dreamed of an electrolytic cell in which the consumed electrode is carbon. The best way to realize the difficulties of this problem is to consider it solved and see what it means. The carbon must be in contact with an electrolyte, and the electrolyte must either be in contact with a second electrolyte, which wets the other electrode, or must itself be in contact with that electrode. This second electrode must almost certainly be metal, as there are no other non-metallic conductors available. The electrolyte in contact with the carbon must be a salt of carbon or must contain a salt of carbon, or it must contain another salt whose positive radicle can be replaced by carbon. Such compounds as the hydrides, nitride, oxides, chloride, bromide or the sulphide or silicide of carbon are not salts in the electrolytic sense. Carbon forms part of the electropositive radicle in the organic radicles, and part of the electronegative radicle in the cyanogen compounds, but it is never a radicle by itself. To sum up the matter shortly in the light of modern theory, carbon never forms ions, and has, therefore, no solution pressure, and can, therefore, give no e. m. f. At ordinary or moderate temperatures carbon is practically inert. Oxidizing agents will attack some forms lightly, and sulphuric acid will attack it. In this latter case the formation of water and its combination with the acid is the determining factor. At high temperatures, oxygen, sulphur, silicon, and to some extent nitrogen and many of the metals, combine with carbon, but there is no dissociable salt of carbon formed. The carbon cell thus seems impossible. Such schemes as Mr. Reed's, ingenious as it is, is not a solution of the problem. It would be simpler to reduce zinc oxide with the carbon, and then put it in a zinc cell. It is hardly necessary to discuss thermopiles or thermo-magnetic engines as possible economical producers of electric power."

OVERVOLTAGE.

In the recently-issued second volume of the "Transactions of the American Electrochemical Society," page 83, some of the remarks made by Dr. F. Haber, in the discussion of Mr. Weightman's paper, appear somewhat ambiguous, as Dr. Haber had no opportunity to revise the stenographer's report. As the matter is of some interest, we give herewith the substance of a letter recently addressed by him to the president of the Society.

Dr. Haber intended to say in those remarks that overvoltage, which is a newly-coined word for an old, well-known phenomenon, refers to the fact that it requires a higher voltage to develop gases on certain electrodes than would be expected from the thermodynamic theory. From his point of view, it means that the gaseous compound is not formed from the ions at one single step, but that an intermediate product is first formed, as, for instance, in the case of hydrogen it may be an alloy of that gas and the metal of the cathode, or a solution or occlusion of hydrogen in or at the metal of the cathode. He emphasized the idea that the properties of this intermediate product were responsible for the phenomenon, although he had to admit that we are not yet quite able to make such a definite statement of this property as will cover the ground perfectly. He gave as an example the behavior of mercury as cathode in dilute sulphuric acid to explain this subject.

SODIUM CHLORID IN ELECTROLYTIC CAUSTIC ALKALI.

BY CLINTON PAUL TOWNSEND.

In a former paper (ELECTROCHEMICAL INDUSTRY, Vol. I, page 23) the writer discussed in a general way the influence of the movement of the products of electrolysis upon the course of the reaction in the electrolysis of sodium chlorid solutions, and referred to the several types of cell which have been proposed or used, considering these types particularly from the point of view of the means employed for checking such movement between the respective compartments of the cell.

In every electrolytic cell capable of producing caustic soda such means are present; in their absence, the cell passes into the type adapted for the production of bleach liquor or chlorate. The idea of means differs, of course, very widely, and may comprise a stationary septum of mercury entirely impervious to a liquid; a moving body of mercury; a diaphragm, one side of which may be unsubmerged in order to allow the product to flow freely from it; a definite direction and rate of liquid flow, or merely such disposition of parts as will avoid or minimize agitation by escaping gases, convection currents or the feed and discharge of the electrolyte.

The purpose of the present paper is to consider a single aspect of this question, viz.: the movement of undecomposed sodium chlorid into the caustic compartment.

Sodium chlorid is soluble in caustic soda solutions to a degree dependent on the concentration of the hydroxid. A solution containing 10 grams of caustic soda per litre is capable of dissolving 308 grams of sodium chlorid, while a solution containing 640 grams of caustic per litre can dissolve only 18 grams of salt. The solubilities of salt in caustic of various concentrations at 20° C. have been accurately determined by F. Winteler *(Zeitschrift fur Elektrochemie,* 7, page 360).

Of the several general types of cell mentioned above, one only is capable of yielding a caustic solution absolutely free from dissolved chlorid. This is the cell, as originally suggested by Vautin and modified by Kellner, and later by Edser, wherein the caustic compartment is separated from the remainder of the cell by a stationary septum (cathode) of mercury, which is pervious to metallic sodium, but not to water or compounds in solution therein. The term "stationary" is here employed to indicate that the mercury is not transferred bodily from one point to another during the operation. An internal movement of the mercury, to aid the slow process of diffusion in transferring the metal from the surface of deposition to that of oxidation, is, of course, essential, since otherwise both the capacity and the efficiency of the arrangement would be very low. The provision of means which should entail neither undue complication of parts nor too great expenditure of energy for producing a sufficiently rapid transfer of the dissolved alkali metal would make this cell the ideal one for the production of pure caustic solutions.

If the body of mercury be moved continuously or intermittently between decomposing and oxidizing compartments beneath a depending partial partition, the mercury itself constituting a seal between the respective solutions, the quantity of chloride which will be transferred from the electrolyzing compartment to the caustic side and the quantity of caustic transferred in the reverse direction depend largely upon the exposed surface of the mercury and the velocity imparted to it. It is essentially a transfer by wet surfaces, and is not considered to affect seriously the commercial operation of the cell. It is a phenomenon entirely different from that to be considered here.

Let us consider next a construction comprising two electrodes of opposite polarity, an outflow opening adjacent to each and a single inlet for the electrolyte, such inlet being situated between the electrodes and serving to produce a flow of the electrolyte in opposite directions from the intermediate part. It will be clear that if the rate of flow of the electrolyte be sufficient to overcome the backward diffusion of the reaction products and their movement caused by other agencies, the cathode liquor will consist only of the hydroxid and chlorid of sodium. If the current efficiency reaches 100 per cent., which can be measurably attained under these conditions with sufficiently rapid flow, the composition of the liquid flowing past the cathode can be readily calculated. A quantity of the sodium chlorid equivalent to the current used has yielded caustic according to the equation

$$NaCL + nH_2O = Cl + H + NaOH + (n - 1)\ H_2O;$$

the proportions of chlorid and hydrate being molecular, but a concentrating effect due to the decomposition of water supervening. The exact composition corresponding to any given current and liquid flow and composition of electrolyte is, of course, readily determined.

The above construction fairly represents in principle the type of "gravity cells." If the flow of the liquid be rapid, assuming that the maximum permissible current density is employed, the current efficiency will be high, but the cathode lye will be low in caustic and high in salt. For the withdrawal of the products and the prevention of secondary reactions, a certain minimum rate of flow is essential, and this rate of flow is, in the cell constructions as yet proposed, too high to admit of thoroughly satisfactory concentrations of caustic.

The ratio which the quantity of salt electrolyzed bears to the total quantity passing the cathode is the decomposition efficiency. There is, at moderate rates of flow, in a cell of the type above referred to, an inverse relationship between decomposition efficiency and current efficiency; and a perfect decomposition efficiency, at even moderate current efficiency, will always be impossible in the absence of means for removing the cathode products from the field of electrolytic decomposition absolutely at the instant of their formation.

The above considerations will make clear the true function and character of the diaphragm in a caustic cell. It is essentially a device for controlling and equalizing the forward movement of the electrolyte and for retarding the backward movement of the products of electrolysis, and thereby permitting the establishment of a new and lower minimum flow for their removal. It is in no sense to be considered as a septum capable of permitting the passage of the electric current, but of preventing the diffusion and recombination of the products in stationary bodies of electrolyte. Yet this latter conception seems to be the common one among workers in the art. The new minimum thus established corresponds to higher concentrations of caustic with equal current efficiencies.

A solution of sodium chlorid saturated at ordinary temperatures corresponds approximately to the formula $NaCl + 9H_2O$. Complete decomposition proceeds according to the equation

$$NaCl + 9H_2O = Cl + H + NaOH + 8H_2O,$$

the per cent. of caustic in the resulting lye being theoretically 21.7. It would appear, therefore, that this figure should be regarded as the maximum concentration of caustic obtainable by direct reaction from any electrolytic cell which depends upon the water of the electrolyte for oxidation of the metal sodium. It is interesting, therefore, to observe that this concentration is easily exceeded; that no sharp break in current efficiency occurs at or near this figure, and that cathode lyes of the approximate caustic content above noted have been found to contain a quantity of undecomposed salt which corresponds nearly to their saturation point.

The cell from which the following curves were obtained need not be further described than by the statement that it was provided with a thin permeable diaphragm, adapted to restrain and equalize the flow of the electrolyte, and a cathode whose form fitted it to serve as a surface for the rapid discharge of the cathode products. The annexed diagram (Fig. 1.) shows in solid lines (A) the percentages of caustic and (B) the percentages of undecomposed salt. The broken curve (C) indicates the saturation curve of salt corresponding to the caustic

found. The analyses from which the curves were plotted were made at forty-minute intervals.

It will be noted of these curves that the caustic attains approximately the supposed theoretical maximum above referred to, and that the undecomposed salt is present nearly to saturation of the caustic. It will be further noted that there is apparently a strong concentration effect, inasmuch as the sum of the salt found, and the salt equivalent of the caustic, is far in excess of the saturation point for aqueous solutions of

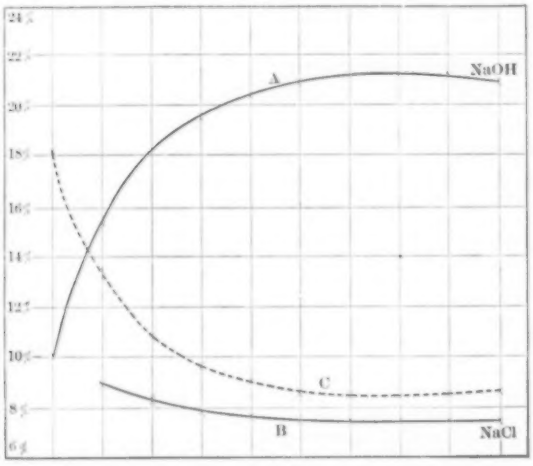


FIG. 1.—SODIUM CHLORID ELETROLYSIS.

salt. This is, without doubt, due in part to concentration of the cathode liquor by loss of water with the escaping hydrogen, in part to the cathodic reduction of hypochlorite and in part to the movement of the salt through the diaphragm under the influence of the difference of osmotic pressure upon opposite sides of the membrane.

These results suggest at once a query as to the relative proportions of caustic and salt in the cathode product of the electrolysis of more dilute sodium chloride solutions. A solu-

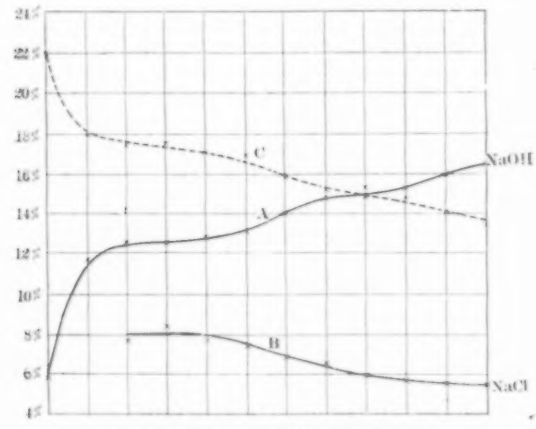


FIG. 2.—SODIUM CHLORID ELECTROLYSIS.

tion corresponding approximately to the formula $NaCl + 15H_2O$ was electrolyzed. The theoretical concentration of caustic obtainable from such solution, if completely electrolyzed without concentration, is 13.7. The results are shown in Fig. 2, curves A, B and C representing, as before, percentages of NaOH, NaCl and the saturation curve of salt in caustic respectively.

The irregular form of the caustic curve in this case, indicating as it does an intermittent progress to concentrations considerably exceeding those theoretically attainable without loss of water, is not easily explained, inasmuch as the electrolyzing current was maintained substantially constant, and the rate of flow of the solution underwent no corresponding variations, but diminished slowly and regularly from the beginning to the end of the experiment, which occupied 440 minutes. The analyses in this, as in the other cases, were made at intervals of forty minutes. The broken curve C, representing as it does merely the percentages of salt required to saturate the caustic of the curve A, is substantially the reverse of the latter. Most peculiar, however, is the close parallelism between the curve B, representing the saturation line, and the curve C, representing actual salt content. The latter parallels the former, the interval between them corresponding to about 9 per cent. of salt.

The electrolyte was then diluted to the composition $NaCl + 18H_2O$ and the curve secured, as shown in Fig. 3. This solu-

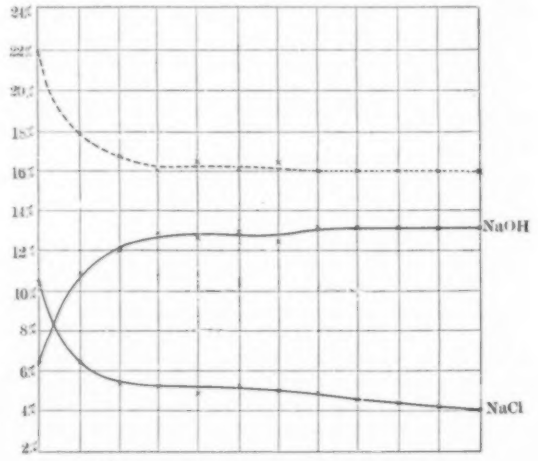


FIG. 3.—SODIUM CHLORID ELECTROLYSIS.

tion, completely converted into caustic without further concentration than is called for by the reaction, should yield a liquid containing 11.6 per cent. NaOH. As in the previous case, the concentration obtained is considerably in excess of this figure. The salt curve B again nearly parallels the saturation line C, but the interval between them is now approximately 11.5 per cent.

These results clearly show the controlling influences of the concentration of the electrolyte upon the salt content of the resulting caustic. In a subsequent note the writer hopes to discuss the character and limits of this relationship.

The history of the development of the diaphragm type of caustic cells is one of the most interesting chapters of electrochemistry, but it is largely a story of individual failure. It is usual to regard the defects of high resistance, low concentration and purity of product and rapid deterioration in use as inherent in cells operating by this method, but the whole tendency of recent work is to the effect that such is not necessarily the case. A diaphragm adapted to perform its true and proper function need neither offer high electrical resistance nor be perishable; it is only when the work of maintaining a separation of the products of electrolysis—a result which should be secured by other means—is imposed upon the diaphragm that it becomes an inefficient tool and a troublesome element of the cell.

International Congress for Applied Chemistry.—The arrangements for the meetings of the electrochemical section of this congress, to be held in Berlin next year, are in charge of the German Bunsen Society. Besides the papers to be read, it is intended to have experts present reports on the following subjects: The scientific and technical problems of the chemistry of calcium carbide; electrochemical methods for preparing organic compounds; the problems of physical chemistry in the manufacture of sulphuric acid; fixation of atmospheric nitrogen.

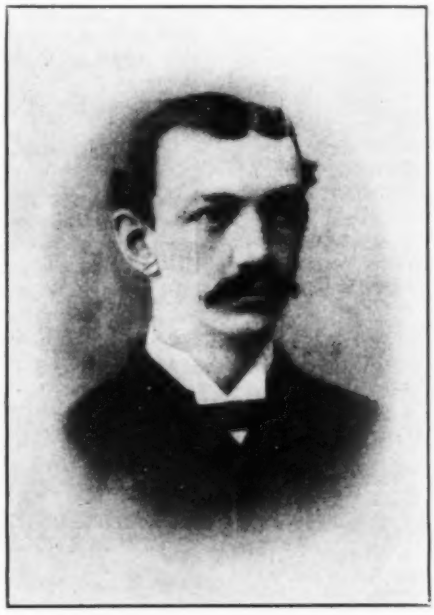
PIONEERS OF ELECTROCHEMISTRY—IV.

HAMILTON YOUNG CASTNER.

Although the subject of this sketch is no longer among the living, yet it is none the less highly appropriate that his name should be placed here among the pioneers of electrochemistry.

Born in Brooklyn, N. Y., on September 11, 1859, educated at a private school, and entering Columbia College School of Mines as a student in chemistry in 1875, Mr. Castner had the great good fortune to come into personal contact during three industrious years with Dr. Chas. F. Chandler, and the warm friendship between teacher and student continued all through his subsequent career. In fact, as a last tribute to its successful student, the School of Mines is about to place in the corridor of its new home, on Morningside Heights, Havermeyer Hall, a bronze tablet commemorative of his name and achievements.

Leaving college in 1878, Mr. Castner established himself as an analytical chemist, and in his spare time was constantly experimenting with chemical and metallurgical processes. He invented an improvement in the manufacture of bone black. Later he became enthusiastic over the possibility of cheapening the cost of aluminum, which, in 1880, was selling at $12 per pound, and he directed his experiments towards finding a cheaper method of producing sodium. His laboratory, on West Twentieth street, three floors high, was filled with furnaces and apparatus, and out of it emerged, in 1886, a successful process for producing sodium by reducing caustic soda by a mixture of iron and carbon, in steel pots, in a regenerative gas furnace. Instead of costing $2 per pound, sodium was thus obtained for about 20 cents per pound, and the way to cheaper aluminum was open. Each pound of aluminum requiring 3 pounds of sodium to reduce it, the saving on the former was easily $5 per pound. The United States patent for this process is 342,897, of June 1, 1886.



H. Y. Castner

Going over to England, Mr. Castner put up an experimental furnace in London, and, on proving his claims to the satisfaction of Sir Henry Roscoe and other chemical experts, the Aluminum Co., Ltd., was formed, and the erection of large works commenced at Oldbury, near Birmingham. (This town is the writer's birthplace, and it was at this time that the writer's personal acquaintance with Mr. Castner began, an acquaintance which, during twelve years, ripened into sincere friendship.)

In connection with this enterprise, Mr. Castner patented improvements in the manufacture of aluminum chloride and the furnaces used in reduction. The plant was extensive and well planned. Mr. Brindley, now manager of the sodium manufacture at Niagara Falls, was his chief of construction. In 1888 this plant was making 1,500 pounds of sodium per day, and therewith 500 pounds of aluminium, which was sold at $5 per pound. But dark days were ahead. The electrolytic processes for making aluminum were being perfected, and the very next year the competition was felt. Prices went down and down, until at last, in 1891, when it sold for 85 cents per pound, the chemical process was forced to acknowledge itself out of the race, although the sodium it used was costing only 10 cents per pound.

At this point Mr. Castner showed his mettle, and actually, by main force of his wonderful energy, saved his company from bankruptcy. With $250,000 invested in a plant which was practically useless and a capital of $500,000 at stake, he turned to find new uses for metallic sodium, and practically created the present sodium industry. He found a method of making sodium peroixde for bleaching purposes; he invented a process for making sodium cyanide from crude ferrocyanide; he exploited the use of sodium in making organic chemicals, such as antipyrin, and the manufacture of chemically pure caustic soda from the metal. With these opportunities for business, his company continued in existence as "The Aluminum Co., Ltd.," but made not a pound of aluminum, making profits on sodium alone.

At this period Mr. Castner became an electrochemist. Driven out of the aluminum business by electrolytic methods, he was quick to perceive the advantages of such processes, and he commenced experimenting on the electrolysis of fused caustic soda. Bringing to this his skill as an analytical chemist, with his experience in chemical engineering, the way was open to him for great achievements. His United States patent of May 12, 1891, describes the electrolytic process practically as it is carried on to-day, and established his pre-eminence in the sodium business more firmly than ever. The need for pure caustic soda, to use in manufacturing sodium, set him to experimenting in the electrolysis of sodium chloride, and by 1894 we had his perfected apparatus and process for the use of a movable mercury floor to a double cell—the most elegant electrolytic process ever invented. (U. S. patents, April 10th and October 30, 1894.) It is unnecessary here to describe that well-known process. The writer saw the 200 horse-power experimental plant at Oldbury, which has since expanded into the 4,000 horse-power plant at Runcorn Point, on the Mersey, and the magnificent 6,000 horse-power plant at Niagara Falls. And we must not omit to record the integrity of the inventor, who turned his inventions over to his once financially ruined company and brought them into such a position that they have made more profit from the soda and sodium business than they had ever hoped to make from the aluminum business. Such a turning of defeat into victory is seldom recorded in industrial annals, and the continued existence of his company is one of the finest monuments to the industry, skill and integrity of Mr. Castner. In connection with this business, numerous patents on details of apparatus, baking of carbons, purification of the brine, etc., attest the ever-active inventive genius.

It is not, however, alone as an inventor that we wish to speak of Mr. Castner's abilities. He possessed the rare combination of high inventive ability, the genius of putting inventions into commercial, working form and good business instincts. He could not only devise, but he could construct, work and manage; and by his attractive personality he could win and hold friends and make his business position secure.

A disposition towards consumption made his health always precarious. The English winter drove him into exile to Florida or the Riviera. In October, 1899, he died at Saranac Lake, N. Y., at the untimely age of forty. His death has been a great loss to the art of electrochemistry, but his life-work will continue to be one of the brightest examples of how to win and to hold success that appears in the annals of that science.

A NOTE ON THE CONDUCTIVITY OF NICKEL OXIDES

By A. L. Marsh.

It seems to be the prevailing opinion that nickel peroxide is a non-conductor of electricity, and that, to render this material of service in the storage battery, it must be mixed with a sufficient quantity of inert conducting material, such as flake graphite, to make the mass a conductor. Mr. Edison uses such a mixture in his new nickel-iron cell. While I have made no direct measurements of the conductivity of the oxides of nickel, it seems to me that the two experiments described below indicate that this compound cannot be classed as a non-conductor.

Hydrated nickel peroxide deposits as a rather dense, black coating on the anode when an alkaline tartrate solution of nickel is electrolyzed. This deposit does not noticeably reduce the current or prevent further deposition of peroxide on its surface. Electrodeposited conducting bodies may be built up one layer upon another, while non-conducting bodies act as porous partitions or diaphragms, through which further action takes place, and each succeeding layer of the material is set free at the surface of the metal electrode, assuming that the metal electrode is unattacked in each case.

In another experiment a cell was constructed having a layer of black oxide of nickel (Ni_2O_3) more than three-sixteenths of an inch in thickness, surrounding a strip of nickel gauze. This oxide, which was partially hydrated, formed the active material of the positive electrode. Spongy cadmium, surrounding a strip of sheet iron, formed the negative electrode. There was no inert conducting substance mixed with the nickel oxide, yet the cell showed a very fair capacity per total weight.

I believe that electrochemically active nickel peroxide is a hydrated compound, and that the one with the proper degree of hydration is a fairly good conductor of electricity compared with lead peroxide.

But little is known of nickel peroxide. The lower oxides have, however, been better studied, and these are the ones used in the battery and from which the peroxide is formed electrochemically.

Nickel sesquioxide may be obtained in at least three different conditions, namely, anhydrous, Ni_2O_3; partially hydrated, $Ni_2O_3\ 2H_2O$, and hydroxide, $Ni_2(OH)_6$. The second, Ni_2O_3, $2H_2O$, is the compound which Wernicke believed to be formed during the electrolysis of an alkaline tartrate solution of nickel, but I think it more likely that nickel peroxide is at first formed and becomes reduced by a secondary action, due to the reducing medium in which it is formed.

There may be an analogy between the sesquioxide of nickel and lead peroxide as regards their conductivity with different degrees of hydration. Anhydrous lead peroxide is a very poor conductor compared with the hydrated peroxide formed at the anode during the electrolysis of a nitric acid solution of lead nitrate, so we might expect to find anhydrous nickel sequioxide a poor conductor compared with the hydrated varieties of the same compound.

Nickel sesquioxide, prepared by heating nickel nitrate; $Ni(NO_3)_2$, is anhydrous, and when this compound was used to form the peroxide electrolytically very poor results were obtained. Poor results were also obtained when the green oxide of nickel was used in the same way. In both of these cases the oxides used were not in the proper condition for rapid and efficient formation into the hydrated nickel peroxide, which I assume to be the compound of nickel of the charged electrode. In these cases an admixture of graphite might have aided the formation. Heat seems to render the oxides of nickel inert, as it does the oxides of the similar metal iron. Lead peroxides can be formed electrolytically from the lower oxide, PbO, prepared by heat, and therefore anhydrous. Heat does not affect the oxide of lead as it does the oxide of iron, for the oxide of lead is readily dissolved by nitric acid, while the oxide of iron becomes practically insoluble after being heated. Nickel being a metal somewhat similar to iron, we should expect its oxide to become less active after being heated, and this seems to be the case in regard to its behavior towards electrolytic oxidation.

Nickel hydroxide is a very bulky compound, and practically the same objections to its use in the storage battery are found as Mr. Edison has found in the use of the bulky hydroxide of iron for the negative electrode of his cell.

In my experience, the best compound of nickel to use in the storage cell is the hydrated sesquioxide, $Ni_2O_3\ (H_2O)_x$, in which x represents a quantity of water less than the hydroxide contains. This compound can be peroxidized electrolytically with ease, and without the aid of inert conducting substances. In preparing this hydrated sesquioxide, I use the following method:

Nickel sulphate is dissolved in water, and by adding a strong solution of caustic soda, green nickelous hydroxide is precipitated. An excess of the caustic soda solution is added, and then a current of chlorine gas is allowed slowly to bubble through the liquid containing the nickelous hydroxide in suspension until that compound becomes jet black and all of it has been oxydized to nickelic hydroxide, $Ni_2(OH)_6$. The black hydroxide is then washed free from alkali and salts, and then spread out in the air to dry. A large shrinkage occurs in the mass, due perhaps to the loss of a part of the water of hydration. The air-dried material is ready for use in the battery.

While I do not think the flake graphite necessary to increase the conductivity of the active mass, especially when the compound is properly prepared, yet I do think that it may perform a valuable service in the positive electrode by preventing the peroxide from falling out of a perforated grid. My experience with the peroxide of nickel has shown that there is but little cohesion between the particles of oxide, even after the mass has been subjected to a considerable pressure. The particles very readily pass through the small openings of the grid, and to prevent this the flake graphite may be of some value.

From the evidence stated above, I think that nickel peroxide should not be termed a non-conductor, even from a practical standpoint, but should be classed with the conductors.

HOW TO DETERMINE THE BEST CONDITIONS IN STORAGE-BATTERY PRACTICE.

By Carl Hering.

In expressing opinions on a storage battery, there are two extremes to which those judging them are likely to go. On the one hand the so-called scientist or theorist, who too often has an unwarranted contempt for matters involving dollars and cents, is apt to lay great stress on such qualities as the efficiency, the internal resistance, the voltage, drop in voltage, etc., ignoring completely the purely commercial considerations.

On the other hand the so-called practical or "self-made" man, who has often not had a proper training in the principles and laws involved, and too often has an unwarranted contempt for what he calls mere theories, generally meaning thereby a good scientific education and ability to make calculations, will be apt to fail to notice serious and often fatal defects in a battery, which, though perhaps not evident at first, are certain to develop later.

When any piece of scientific apparatus, as the original storage battery was, is to be used industrially, it is just as important to consider the questions of dollars and cents as the purely scientific features. The proper way to judge a battery as a commercial article is to give proper weight to both.

Dynamos and motors might, perhaps, be built with as high an efficiency as 99 per cent., but every well-trained electrical engineer knows that they would then become so expensive that no one would buy them. They would be a scientific success,

but a commercial failure. On the other hand, very cheap ones could be built of very low efficiency, but a person who can calculate in advance will often find that this continual loss of power will in the course of time amount to more in cost than the original difference in price. There is always a proper mean between these two extremes, and it is the duty of the trained engineer to determine this.

As this is well understood among those who make, sell or buy dynamos and motors, it is strange to see that the same reasoning is not more generally applied to storage batteries. One reason, undoubtedly, is that the corresponding calculations are not quite so simple, and the required data are not always at hand. But this does not excuse ignoring these questions completely.

A very similar case is found in the determination of the most economical use of incandescent lamps, which is also somewhat complicated, and although the author called attention to a method nearly ten years ago, and showed* how the conditions of the lowest cost in their use may be determined, it was not until recently that the principles involved were begun to be recognized.

As the conditions are in some respects somewhat similar in determining the most economical use and construction of incandescent lamps, and the most economical use and construction of storage batteries, and as the former method may not yet be generally understood, it may be briefly described here to facilitate the understanding of the latter.

A lamp may be made to have a long life, and the cost of the lamp itself per hour of its life will therefore be small. The efficiency, however, will then be poor and the cost of the current per candle-power hour will be relatively high. On the other hand the lamp may be made to have a high efficiency, but a short life, and the cost of the lamp per hour then becomes greater, while that of the current becomes less. The gradual deterioration by blackening of the globe and the reduction in efficiency may be included in the above by using a candle-power hour as the unit instead of the lamp hour.

Now the total cost to the user is, of course, the sum of these two; it is evidently immaterial to him how this cost is divided between the two, as he is only concerned with the total. This total cost will rise by going to either of these extremes, hence there must be a minimum cost somewhere between the two, and the question is to find the conditions under which this minimum is reached. This minimum, of course, will be different for different costs of the lamps, and for different costs of the power, but the method of determining it is the same for all.

The way to do this is to plot two curves, one of which shows for each successive hour in the life of a lamp, the total quantity of light given off by it in candle-power hours, from the time the new lamp was first started. The other curve gives for each successive hour in the life of the lamp, the total cost of this light; that is, the original cost of the lamp added to the cost of all the energy consumed by it from the time the new lamp was first started, up to the respective hour. If for each hour this total cost, at that hour, as given in the second curve, be divided by the total quantity of light delivered up to that hour, as given by the first curve, the quotient will be the average cost per candle hour from the start to that hour. When these quotients are plotted as a third curve it will be found to have a minimum point; that is, a point where this average cost will be the smallest. It will be cheapest to discard the lamp at that hour of its life even though it may not be broken or greatly blackened.

The general method of finding such a minimum is as follows. First of all, there is the specific quantity under discussion, whose minimum (or perhaps maximum) is to be found; it was the average cost of the light per candle hour in the above case; in accumulators it might be cost of the battery per kilowatt hour capacity per discharge, or the length of run of an automobile driven by it (in which case it is the maximum that is sought), or the cost of the battery per mile run of an automobile before the battery must be renewed, or the number of miles run per dollar of cost of battery, or the cost of a kilowatt hour of the energy delivered, etc.; with batteries there are a number of such quantities. This quantity is usually made the ordinate, that is, the vertical scale of the final curve; it will, of course, always be different from either of the vertical scales of the two original curves, as will appear later.

The next step is to be reasonably sure that a minimum (or maximum) value can be expected. For instance, the first cost of a lead battery per kilowatt hour capacity will (in general) go on increasing indefinitely when the weight is increased and will never have a minimum, its least value will be when the weight is nothing, which in practice simply means the lighter the cheaper. The general rule to find in advance whether there is likely to be a minimum is to see whether the quantity under consideration will *increase* when one goes to both of two opposite extremes, if so, there must be a minimum somewhere between them. For instance, if one continues to decrease the weight of a battery, its life will be shortened and the cost of renewing the battery will increase the total cost per kilowatt hour capacity; on the other hand, to make it extremely heavy will increase the life, but again increase the total cost as the original cost will then be high; there is, therefore, a minimum somewhere between these two extremes.

The next step is to select the other ordinate of the curve; that is, the quantity or units in terms of which the time or condition of the occurrence of this minimum is expressed. In other words, it is some convenient quantity or scale which shows *when* this minimum is reached, while the other one shows *what* or *how much* this minimum is. In the case of the lamp it was the time in hours, and it showed at what hour the cost was a minimum. There may often be some latitude in the selection of this quantity as it enters into the question only as a sort of a scale to show when the minimum is reached. With storage batteries it might be the weight, the life, the number of cells, etc. The only conditions in its selection are that it must not, of course, be the quantity whose minimum is to be determined, and it must be the same for all the three curves, that is, for the two original curves and for the final curve. For the latter reason its selection will be governed largely by the data at hand, or which can be acquired. This quantity is usually made the abscissa, that is, the horizontal scale of the curve.

Having thus selected the two final scales to be used, the next step is to plot from known data the two (or perhaps more) original curves from which the final one is to be determined either by the addition, subtraction, multiplication or division of the two (or more) corresponding ordinates. This is shown best by the examples which follow.

The last step is to calculate and plot the final and desired curve from the two (or more) given original curves of data, the nature of the calculations, of course, depending upon what quantities the original and final curves express. This is best done roughly at first to find if there really is a minimum point and approximately where it is, as it may be beyond the practical limits of construction or use; after locating it approximately, calculate more accurately numerous points in the vicinity of the minimum point and draw the curve through them. The minimum value is then read off on the vertical scale, and the condition when this minimum is reached is read off on the horizontal scale. All that was said about the minimum point applies, of course, equally well to a maximum point.

Minimum and maximum points can also, of course, be readily calculated algebraically by means of the differential calculus, but this requires that the original data be given in the form of algebraic equations, and in many cases, especially

* Transactions of the American Institute of Electrical Engineers, vol. 10, 1893, p. 65.

when the original data is all obtained from experiments and tests, it is quite difficult and often somewhat hazardous to determine these equations, the amount of work being often greater than the drawing of the curves. Moreover, such equations are generally only approximate, and the errors thereby involved may change the location or amount of the minimum point quite appreciably. Another advantage of the graphical method with the curves, is that it is much easier to understand and safer to use, for those who are not very familiar with the differential calculus.

To illustrate the application of the above described general method of curves for determining the best conditions in storage-battery practice, a few specific examples are here given in the adjoining figures. It is to be noted, however, that the curves given are intended only to illustrate the method, and not to give actual values, for in some cases they have been exaggerated or distorted to serve their purpose better as examples of the method; moreover the original data may sometimes be so different from those indicated that there may not be a minimum at all, or it may lie beyond practical limits.

The numerical values of the divisions of the scales have been purposely omitted; the horizontal ones must, of course, be the same in all three curves of each example, and the vertical ones are generally very different in amount and always different in the thing they represent.

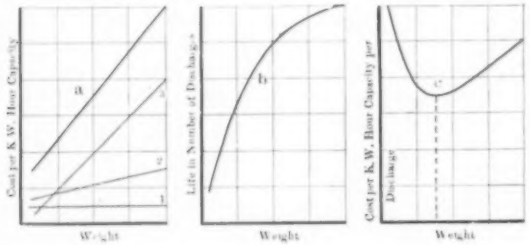


FIG. 1.—COST OF BATTERY AS FUNCTION OF WEIGHT.

The three curves of Fig. 1, show how to determine for what weight of cell the cost of the battery itself (not including the cost of the power) will be least per kilowatt hour capacity per discharge. The first two curves *a* and *b* give the original data, and the third one *c* gives the final result. The horizontal scales in all three are the weights, as that is the quantity to be used to indicate *when* the minimum point is reached. It might have been made the number of cells or perhaps some other quantity according to what one wants to take as the variable measure.

Curve *a* gives the different costs of a battery per kilowatt hour capacity when made of different weights of plates. It is made up of curve 1, which may represent the cost of forming or pasting, and will be the same for all weights, as the amount of active material is the same in all, because the capacity is assumed to be the same. Curve 2 is the cost of the jar and fixtures, which increases only slightly as the plates become thicker. Curve 3 is the cost of the lead, which increases in direct proportion to the weight. Curve 4 is the sum of these three and is the total cost, which is to be used in determining curve *c*, the subsidiary curves 1, 2 and 3 being merely given here to show how the curve *c* is itself determined.

Curve *b* gives the life in number of discharges for increasing weights; for extremely thin, light plates the number of discharges is small, it then increases as the plates are made thicker, but not as fast as the weight.

Curve *c* is the final curve desired. It is obtained by dividing, for each weight, the vertical distances or ordinates of curve *a* by the corresponding ones of curve *b*. This gives the cost per kilowatt hour of battery per discharge, and it will be seen to have a minimum value at a certain weight.

Fig. 2 shows how to determine for what weight of battery the length of the total run is greatest, for an automobile driven by it. This is a case of a maximum value. Having given an automobile of definite weight, a very light battery will run it a great distance per discharge, as there will be less dead weight of battery to carry, but the battery will have a short life, that is, it will not stand a great number of discharges, hence the total distance before the battery must be replaced, will become less. On the other hand to make it very heavy will increase the life in number of discharges, but there will be such a heavy weight to carry that the length of run for each discharge will be small. There is, therefore, probably a

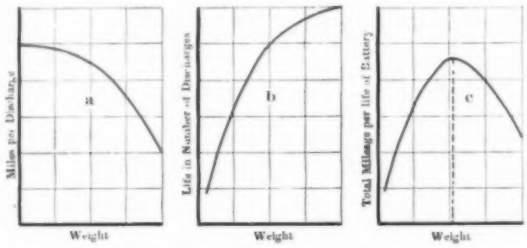


FIG. 2.—WEIGHT OF AUTOMOBILE BATTERIES.

certain weight at which there is a maximum value of the total mileage before the battery must be renewed.

The horizontal scale in all these three curves of Fig. 2, is the weight, as we want to know at what weight of battery this maximum occurs.

The first curve *a* gives the miles run per discharge, for batteries of different weights; this is great for a light battery and becomes less as the weight is increased. Curve *b* gives the life in number of discharges before the battery must be replaced by a new one; this is small for a light, short-lived battery, and becomes longer as the battery is made heavier. Multiplying each ordinate or vertical distance of curve *a* by the corresponding one of curve *b*, evidently gives the total length of all the runs that a battery will stand before it will give out. This gives curve *c*, which is the one desired and which shows that for a certain weight the total distance becomes greatest.

Had the horizontal scales been made cost, the result would have shown at what cost of battery this total run would be greatest.

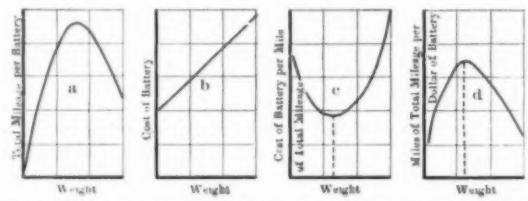


FIG. 3.—COST OF AUTOMOBILE BATTERIES AS FUNCTION OF WEIGHT.

The first three curves of Fig. 3 show how to determine at what weight of an automobile battery, the cost of the battery per mile of its total life, is a minimum. Curve *a* shows the total mileage per battery during its life; it is the same as the final curve *c* of the example in Fig. 2, thus showing how one can go from one curve to others, as in the present example this curve is used as original data. The second curve *b*, gives the cost of the battery when made of different weights. The third curve *c* is obtained by dividing the ordinates of the second curve *b*, by those of the first *a*, and it therefore shows at what weight of battery the cost of the battery is least per mile of its whole life, which are the conditions sought.

Instead of obtaining the minimum curve *c* by dividing *b* by *a*, a maximum curve may be obtained by dividing *a* by *b*; this is shown in curve *d*, which then shows at what weight the total mileage is greatest for the whole life of a battery and per dollar cost of the battery. Curve *d* is evidently only the recip-

rocal of curve *c*, and it is a mere matter of choice between them, as the ultimate result is the same in both.

The three curves of Fig. 4 show how to find at what age in its life is the average cost of one kilowatt hour of energy given out by it, a minimum. It takes into account the gradual depreciation of the capacity of the battery, and it differs from the other examples in that the curves are what are called integration curves; that is, the vertical distances represent totals, or the summing up of all the previous costs or amounts of energy up to that point, and therefore one can, from such values, find what the *average* value has been up to any particular age of its life. This case is quite similar to the one above described concerning the best age of incandescent lamps.

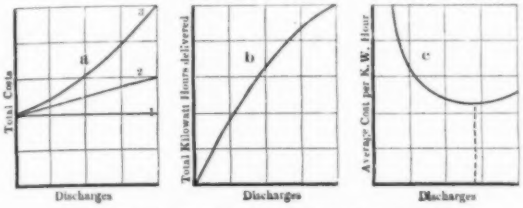


FIG. 4.—AVERAGE COST OF ENERGY OF A BATTERY.

It is here assumed that as the battery gradually depreciates, the amount of energy given out by it per discharge becomes less and less, although the amount put into it is the same. During the first part of its life the average of the total cost of both energy and battery will be great, because the first cost of the battery itself distributed over comparatively few discharges will be relatively great. On the other hand, if the battery is used for very many discharges its first cost per total kilowatt hours delivered will become very small, because the total number of kilowatt hours delivered by it during the many repeated discharges is very great. But owing to the depreciation of the capacity, the cost of the power delivered by it becomes greater because the capacity is reduced, although the power for charging it remains the same; therefore the average of the total cost of a kilowatt hour of energy delivered, including both the cost of power and battery, will be least at some age between these two extremes.

The horizontal scales in all of them represent the age or life stated in number of discharges. Curve *a* gives the *total* costs paid out up to the end of each discharge; it is made up of several subsidiary curves 1, 2 and 3. Curve 1 is the original cost of the battery, which, having once been paid, is therefore the same for every ordinate. Curve 2 represents the depreciation in the cost of the battery; it is here shown as based on a certain sum of money which must be charged or laid aside at every discharge, so that at the end of the life of the battery it equals the amount necessary to renew the worn-out parts; but as has already been described it is a summation curve, each value of which is the *total sum* which has thus been laid aside from the beginning up to that particular discharge. This curve 2 is moreover drawn above curve 1, instead of beginning at the origin as it should if it were by itself, as the ordinate of the two curves are hereby added, and the ordinates of curve 2, in the way it is drawn, then really are the ordinates of curve 1 added to the depreciation. The distances between curves 2 and 3 represent the total cost of the power given out in the successive discharges, and as has already been stated, this increases because the amount put into the battery is the same, but the discharges grow less and less owing to the depreciation of the capacity. As before, these values represent the cost of the total power from the start and not simply for each discharge. These three curves having been drawn over each other, the last one, No. 3, at once represents the sum of all three. It should be remembered, however, that each ordinate of the last curve 3 represents the sum of all the previous costs up to that discharge, thus giving the *total* cost of the battery, the cost of all the depreciation, and of the total energy in all the previous discharges. This summation may be made for every discharge or for every 10 discharges, or in fact for any convenient period, provided only that the period is always the same; the curve is, therefore, really a step by step line, but the steps are supposed to be so frequent that the curve becomes rounded off. Such curves in which all the previous costs are added together up to each discharge, usually rise very rapidly, hence the units of the vertical scale are usually made small, so as to shorten the height of the curve.

Curve *b* simply gives the useful kilowatt hours given out by the battery up to the end of each discharge of its life; here, again, each ordinate is the sum of all the outputs of the battery in all the preceding discharges, that is, it is the total output of the battery from the start up to the end of that discharge.

Curve *c*, which is the ultimate one desired, is obtained by dividing the ordinates of curve *a* by the corresponding ones of curve *b*. By thus dividing the total money paid out up to the end of each discharge, by the total useful energy received from the start up to the end of that discharge, the result will be the *average* cost per useful kilowatt hour delivered between the start and that discharge. This average is at first quite large on account of the first cost of the battery, it then diminishes, but later on rises again on account of the great waste of energy toward the end of the life; hence it has a minimum value at a certain life, as shown by this curve. At that age it is cheaper to renew the battery than to continue to use it, even though it may not seem to be worn out.

When the final curve is relatively flat at and near the minimum point, it means that the minimum point is not sharply defined, and that one may safely go some distance to one side or the other of the theoretical point without affecting the result materially. But if the curve at the minimum point is sharp and pointed, it means that it is sharply defined, and that one should approach the exact point as closely as possible.

As has already been stated, all these curves are intended only to show in a general way how such determinations can be made, they are not intended to give any absolute values. The curves will naturally vary quite greatly with different batteries, and those of Fig. 4 will vary with different costs of the power, and when actual figures are used the minimum point may fall outside of practical limits. For instance, in the last case, Fig. 4, curve *c*, the minimum point might occur at a later time than the natural life of the battery, and it would therefore be impossible to reach this point. But even then the calculation has a value, as it shows conclusively that the life of the battery is shorter than that required to give the best result. If, on the other hand, the minimum point occurs much earlier than the natural life, it shows that the battery has an unnecessarily long life, and it would be cheaper to force it, or to make it lighter. In this way such calculations as those here described may often lead one to approach, or even arrive at, the very best conditions of operation or construction.

CALCIUM CARBIDE AND ACETYLENE.

Calcium carbide, CaC_2, was prepared by a purely chemical method in 1862 by Woehler, who heated an alloy of zinc and calcium with an excess of carbon. The great calcium carbide industry of the present time, however, depends upon the electric-furnace process. Calcium carbide was produced in a small way by the Cowles brothers in their electric furnace while it was used in Cleveland. The production on a commercial scale in the United States dates from 1894, when Thomas L. Willson developed the process in Spray, N. C. Since that time the calcium carbide industry has made enormous progress—which was even too rapid in various countries to be sound—and at present it is one of the most important electrochemical industries.

The principal point which decides the economical problem of

the calcium carbide industry is, of course, to find well-paying uses and applications for calcium carbide. The use of calcium carbide as a reducing agent for various metallurgical processes has attracted considerable attention in recent years. This interesting subject shall be dealt with in a separate article in this journal in the near future. The main use of calcium carbide is, of course, at present the production of acetylene, and the economical problem of the calcium carbide industry is, therefore, at present most intimately connected with the problem to find new uses for acetylene gas and to extend further the commercial use of acetylene lighting.

We will begin with a very brief review of the chemistry of the subject. Calcium carbide is prepared by heating in the electric furnace a mixture of lime, CaO, and coke. At the high temperature of the furnace, the calcium, which is formed by the action of carbon on lime, unites with carbon and forms calcium carbide, CaC_2. Acetylene, C_2H_2, is made by decomposing calcium carbide with water, according to the equation

$$CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2.$$

The combustion of acetylene gas takes place according to the equation

$$2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O.$$

This last equation represents, however, the total combustion process. According to this equation, the combustion would be

WORKS OF UNION CARBIDE CO., NIAGARA FALLS.

heptamolecular, while it has been pointed out that chemical processes are almost always mono- or bimolecular, and that in such cases in which a reaction is represented by an equation indicating several molecules it is probable that several intermediate reactions are involved.* Indeed, from a kinetic standpoint, polymolecular reactions should be expected to be rare, because there is only a slight probability of a large number of molecules coming together in just such a way that the reaction can take place. A reaction is much more likely to proceed in a way which involves the interaction of only very few molecules. This has, indeed, been found to be the case with our reaction, as Bone and Cain proved that there are different steps, the first of which is represented by the bimolecular equation

$$C_2H_2 + O_2 = 2CO + H_2,$$

while CO and H_2 then burn further to CO_2 and H_2O.

While the calcium carbide and acetylene industries are closely connected, and depend the one upon the other, they are not connected financially, both industries being operated separately and backed by separate capital.

The electric-furnace process of making calcium carbide, as worked by T. L. Willson in 1894, was discontinuous. One of the most important improvements in the development of this industry was accomplished by Charles S. Bradley, who made the process continuous. A general outline of the process, as it is worked at present by the Union Carbide Co. at Niagara Falls, was given by J. W. Richards in Electrochemical Industry, Vol. I, page 22. A large amount of the power of the new water-power plant at Sault Ste. Marie has been contracted for by the same company for the purpose of making calcium carbide. We hope to publish a detailed article on the technical problems in the calcium carbide manufacture in the near future.

Concerning the theoretical yield of carbide furnaces, a number of calculations have been made, which are especially interesting in one point, as they show how different results are obtained in such calculations of the theoretical yield, on account of the uncertainty of the assumptions made. J. B. C. Kershaw has given an interesting summary of the results obtained by nine different authors. The kilowatt hours theoretically necessary to produce one metric ton (2,200 pounds) of calcium carbide, containing 80 per cent. carbide, vary between 1,523 and 3,293 (London *Electrician*, November 23, 1900, pages 164 and 245). The same author also gives figures from actual practice. These figures still vary considerably, but he believes that the most reliable figures for the kilowatt hours necessary to produce one metric ton of calcium carbide, containing 80 per cent. of carbide, is between 3,800 and 4,100 kilowatt hours.

While the calcium carbide industry in the United States is in the hands of a single company, and is developing along steady and conservative lines, the development in Europe, especially on the Continent, was characterized by the sudden erection of a great many plants, with a resulting enormous overproduction. The crisis which then set in was inevitable. Many European calcium carbide plants either stopped operation entirely or undertook the production of other electrochemical products more profitable under the existing conditions. It is estimated that on the European continent, allowing a reasonable rate of increase in the consumption of acetylene, it will probably require ten years before the demand for calcium carbide equals the present manufacturing capacity (*Mineral Industry*, vol. 10, p. 74).

Some remarks on page 453 of volume 8 of the *Jahrbuch der Elektrochemie*, which has just been issued, are very interesting in this connection. It is pointed out that the insufficient demand cannot be considered to be the only reason of the industrial European crisis, but that an important point is the fact that it is not at all easy and cheap to make calcium carbide of the good quality required for acetylene manufacture, especially if the raw materials are not pure.

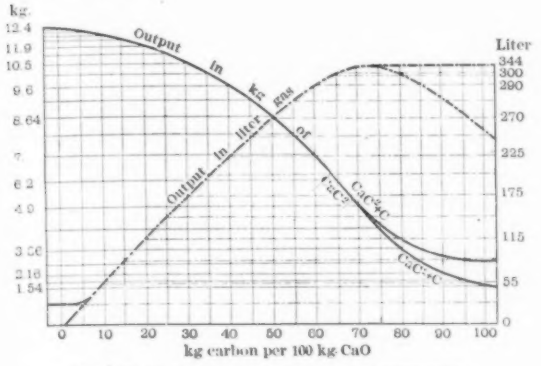
Mineral Industry (vol. 10, p. 75) sets forth some important points in this connection, explaining the better condition of the American industry. In Europe the prevailing custom is to remove calcium carbide from the furnaces by the so-called "tapping" process, while in America the ingots are taken directly from the furnace. It is now conceded that a more uniform quality can be produced by the latter method, and the greater purity of the raw materials in America yields a higher grade of calcium carbide than that generally produced in Europe.

An interesting investigation of the relations between the output of calcium carbide and of acetylene under different conditions of manufacture was made by Keller, of the Compagnie Electro-Thermique Keller, Leleux et Cie, in Paris. Its results were presented to the Third International Acetylene Congress in Paris, and may be seen from the adjoining diagram.

In the plants at Meran and Milan, the average current used in the furnaces was 7,500 ampères at 30 volts. The left-hand scale of the diagram gives the number of kilograms of carbide per 24 kilowatt hours; the right-hand scale gives the number of liters acetylene gas (at 760 mm. pressure and 15° C.) per kilogram of "carbide" obtained in that case. The scale of the axis of abscissas gives the number of kilograms of carbon per 100 kilograms of lime put into the furnace. If the mixture used in the furnace consists of 100 kilograms CaO and 65 kilograms C, an output of 6.2 kilograms calcium carbide per kilowatt day and a development of 300 liters acetylene per kilogram

* Holleman, Inorganic Chemistry [Cooper], p 198 and 239.

carbide were obtained. If a mixture of 100 kilograms CaO and 60 kilograms C is used, an output of 7 kilograms CaO per kilowatt day and a development of 290 liters acetylene per kilogram carbide were obtained. This shows that 1 kilowatt day yields in the first case 1,860, and in the second case 2,030 liters of acetylene.



OUTPUT OF CALCIUM CARBIDE AND ACETYLENE.

As we said before, the future of the calcium carbide industry is intimately connected with the future of the acetylene industry, and it is a very favorable symptom that both industries show at present in this country a steady and healthful growth and progress. True, the use of acetylene for power purposes may still be said to be in an experimental stage, and it is doubtful whether the acetylene motor will ever find a very extended use for general power purposes, but the use of acetylene as an illuminant is extending steadily and on a sound basis. This was not always so.

From the beginning, many would-be inventors were attracted by the apparently very simple problem of generating acetylene gas by bringing calcium carbide and water together. The list of acetylene apparatuses patented in Washington numbers about 1,000. It was overlooked that the problem of acetylene lighting must be considered with due regard to the chemical principles of the combustion of inflamable gases.

In the last years the problems involved in acetylene lighting were carefully studied, and the main principles are now well understood, with the result that reliable and safe apparatuses are now on the market. And it seems safe to conclude that, under these conditions, and on account of the excellence of the acetylene light itself, its use will increase steadily and rapidly, especially for certain purposes and in certain parts of the country. The fine display made by the acetylene interests at the Buffalo Exposition has largely contributed to the present growth of the acetylene industry.

THE STORAGE BATTERY AS AN ELECTROLYTIC CELL.

BY C. J. REED.

All galvanic batteries, whether secondary or primary, are electrolytic cells, although electrolytic cells are not all galvanic batteries.

In order to understand thoroughly the relation of primary and secondary batteries to other electrolytic cells, we must first have a clear conception of the nature of an electrolytic cell, or electrochemical system, as it should more properly be called. We must understand the fundamental process of electrolysis, which is alike in all such systems, and which forms the basis for a definition of electrochemical action.

It may seem superfluous at this late date to revert to such elementary and fundamental principles, but there appears to be a surprising lack of clear conceptions on this subject, even among those who are supposed to know it thoroughly.

A short time ago a certain professor of physics in a well-known university made the statement, in the presence of the writer, that the *slightest external electromotive force* is sufficient to send a current in either direction through any electrolytic cell. On being asked whether this statement applied to an electrolytic cell consisting of an electrolyte of sulphuric acid, a cathode of lead and an anode of lead peroxide, he replied: "Oh, that is a storage battery." This answer showed that, in his opinion, a storage battery was not included in the category of electrolytic cells. His conception of an electrolytic cell was probably limited to an *electroplating* cell.

Conceptions of this kind are our stumbling blocks, and are the source of innumerable, unnecessary hypotheses and assumptions, invented for the purpose of explaining imaginary inconsistencies in nature.

There is no distinction to be made between electrochemical and electrolytic action. Both of these terms define the same fundamental process, which is perfectly distinct from all other processes in nature, and is the characteristic of all primary and secondary galvanic (voltaic) and other electrolytic cells. Not only is this process perfectly definable in terms applicable to all cases, but the mechanism required for its operation is definitely and universally the same.

This fundamental characteristic of electrochemical action is *change of chemical valence or combining capacity* in a particular manner. This change is always produced whenever an electric current passes from an electrode to an electrolyte, or from an electrolyte to an electrode. The change of valence is always in a specific direction at the cathode, and is always of the same quantity and in the opposite direction at the anode; but is never in both directions at the same place. At the cathode the change of valence always tends to liberate an electropositive body from combination, and always tends to cause an electronegative body to enter into combination. At the anode the change of valence always tends to liberate an electronegative body from combination, and always tends to cause an electropositive body to enter into combination. This is the distinguishing characteristic of all electrolytic or electrochemical action, and the only one.

There are other results which generally accompany the passage of an electric current through an electrolytic cell, but they are not characteristic. For example, a particular substance is generally transported through the electrolyte in a particular direction with reference to the current as a result either of the chemical changes or of the current, but this is not always so. Lead, thallium, sulphur, nitrogen, silver, gold, manganese, and many other substances are sometimes transported during electrolysis to the cathode, sometimes to the anode, and some of these substances may be transported towards both electrodes simultaneously. There is no other universal change or effect produced by or in electrochemical action, except the characteristic changes in valence above referred to, which is available for defining electrolysis.

Changes in chemical valence are of frequent occurrence in ordinary thermochemical reactions, but in those cases the opposite changes in valence occur in two atoms or atomic groups which are in intimate molecular contact with each other; while in all electrochemical reactions the atoms undergoing opposite changes of valence are never in contact with each other, but are always at the terminals of a body of electrolyte which intervenes between them, and in which there is no change of valence. Whenever there is a change of valence in any chemical reaction, thermochemical or electrochemical, it is always of the two kinds above mentioned. There never can be an increase of electropositive valence without an equal simultaneous increase in electronegative or decrease in electropositive valence. Nor is there ever a decrease in electropositive valence without an equal simultaneous decrease in electronegative or increase in electropositive valence. The essential and universal difference between thermochemical and electrochemical reactions is that, in thermochemical reactions, these two oppo-

site changes of valence take place in two individual atoms or atomic groups which are at the same place and in contact, the energy change being from chemical energy to heat and from heat to chemical energy; while in electrochemical reactions the two opposite changes in valence take place in atoms or molecules which are not in molecular contact, but are physically separated by an intervening compound conducting body, which undergoes no change of valence, the energy change being from chemical energy into electrical or from electrical into chemical energy.

Having accepted this conception of the nature of an electrolytic cell, we are prepared to consider the relation between storage batteries and other electrolytic cells.

The difference between galvanic batteries (whether primary or secondary) and other electrolytic cells is entirely one of *energy*. In the nature of the electrolytic process there is no difference whatever.

In every chemical change there is always a transformation of energy. Either chemical energy is converted into another form or some other form of energy is converted into chemical. There are chemical changes in which no changes of valence occur, but we are not particularly concerned with changes of this character. They are called reactions of double decomposition, and the energy transformed in reactions of that kind is always comparatively small. In chemical reactions resulting in changes of valence, there is generally a transformation of a large amount of energy. In all chemical changes the transformation of energy must take place where the change in matter occurs. In a thermochemical reaction the transformation of this energy must all occur at the single point where the two reacting molecules or atoms undergoing the change of valence are brought in contact. In electrochemical reactions the transformation of energy corresponding to any change of valence must also occur at the point where the matter undergoing the change is located. We have seen that in electrochemical changes the changes in matter must necessarily occur at *two* different points. Hence, in an electrochemical action the transformation of energy must always occur at two different points, namely, at the terminals of the electrolyte; that is, at the two junctions of the electrolyte with the electrodes, where the corresponding changes in matter occur. The quantity of energy transformed at each of these two points will, in all cases, depend upon the nature of the substance undergoing a change of valence and the energy corresponding to such change. In such changes the energy transformed, or at least a great part of it, will always be in the form of electrical energy, either before or after the transformation; whereas in thermo-chemical reactions it will always be in the form of radient energy (heat or light).

In the electrochemical reaction, however, the electrical energy, if it appears after the transformation, may be immediately converted into heat by bringing the electrodes electrically to the same point; that is, by connecting them with an electrical conductor of low resistance, or by short-circuiting the cell. In this case the energy (heat) is evolved not only at the two electrolytic junctions, but throughout the entire system, as it would be in a thermo-chemical reaction, with the reacting components uniformly distributed.

The current strength is always the same at both electrodes of an electrochemical cell, and therefore an electromotive force must always be either developed or absolved at each electrode proportional to the transformation of chemical into electrical or of electrical into chemical energy at that electrode.

It follows from the above statements that, in any electrolytic cell, there is always developed at an electrode an electromotive force tending to increase the current, if chemical energy is changing into electrical energy at that electrode; that is, if the change of valence diminishes or dissipates chemical energy, and an electromotive force opposed to the current if electrical energy is changing into chemical energy; that is, if the change of valence at the electrode increases or accumulates chemical energy.

It is evident that electrical energy may be evolved at one electrode of an electrolytic cell and simultaneously absorbed at the other; that it may be evolved at both electrodes simultaneously or absorbed at both electrodes simultaneously, and it is further evident that the quantities of energy evolved or absorbed at the two electrodes may be equal or unequal, depending upon the nature of the substances concerned in the reaction.

Remembering that whenever electrical energy is evolved, chemical energy disappears, and whenever electrical energy is absorbed, chemical energy is generated, we see that, if the sum of the changes at the two electrodes evolves electrical energy, the cell or system as a whole is acting as a source of electrical energy, or it is a galvanic battery in the process of discharging. If the sum of the changes at the electrodes absorbs electrical energy, the system is acting as an accumulator or generator of chemical energy. If the chemical change at one electrode is equal and opposed to that of the other, as, for example, when the chemical change at one electrode is reversed at the other electrode, the cell as a whole will neither generate electrical energy nor accumulate chemical energy. Such a cell can neither oppose an electrochemical electromotive force to the passage of a current in either direction nor produce a current in either direction. A cell of this kind requires for the passage of an electric current through it, an external electromotive force sufficient only to overcome the resistance of the materials and the thermo-electromotive forces generated by the current itself. Electrolytic cells of this kind are, in common parlance, generally called simply "electrolytic cells," but have no specific name to distinguish them from batteries.

Electrolytic cells which are capable of generating electrical energy at the expense of their chemical energy have, from that circumstance, received the general name of batteries. The writer has suggested elsewhere that electrochemical systems which generate neither electrical nor chemical energy be called *agenic*.*

Every electrolytic cell which generates electrical energy when a current passes in one direction will generate chemical energy when the current passes in the opposite direction. Every cell, therefore, which acts as a battery when the current is in one direction is necessarily a generator of chemical energy when the current is in the opposite direction. Such cells the writer has described as *electrogenic* when they are generating electrical at the expense of chemical energy (discharging), and *electrothanic* when they are generating chemical at the expense of electrical energy (charging).

The question often arises as to what constitutes the difference between a primary and a secondary or storage battery. There is evidently no difference at all in the cell, but a difference only in *the manner of using* the cells and in their origin. If a battery is manufactured without the aid of an electric current, and is thrown away after its chemical energy is once dissipated, it is called a primary battery. If the cell has its chemical energy restored after discharge by passing a current in the opposite direction, it is called an accumulator or storage battery.

There is a distinction to be made, however, between accumulators and storage batteries. An apparatus may generate chemical energy without actually storing it. The fact that every galvanic battery will generate chemical energy when a current is passed through it in the direction opposed to its electromotive force does not signify that it will necessarily *store* the chemical energy thus generated. Herein lies the practical difference between a primary battery and a secondary or storage battery. There are very many cells in which this generated chemical energy is not available for the generation of electrical energy, on account of the purely accidental circum-

* "Electrochemical Action," Journal of the Franklin Institute, May-June, 1901.

stance that the chemical products formed are mechanically lost in the process of generation. These accidental mechanical losses of material in certain cells or types of cells, however, do not constitute an essential feature on which a classification of electrochemical cells into reversible and non-reversible should be founded. Such a classification implies that there are non-reversible electrochemical reactions, which is not true.

If any of the products of the electrochemical reaction formed in charging or discharging a battery are allowed to escape as a gas, or allowed to fall out of the electrolyte as an insoluble precipitate, or are allowed in any other manner to get out of the circuit, they cease to be a part of the electrochemical system, and, of course, cannot be available in that system for a subsequent operation.

In order to illustrate the foregoing statements by a familiar example, let us assume an electrochemical system to consist of an electrolyte of dilute sulphuric acid and electrodes of platinum. On passing a current through this system, the electrochemical changes at the electrodes will form at the cathode a hydride of platinum, and at the anode an oxide of platinum, the oxygen and hydrogen being derived from the decomposition of the electrolyte. These compounds of platinum have now become the electrodes of the system, and have replaced the original platinum electrodes, the platinum having been exhausted in the formation of these platinum compounds. This electrochemical reaction absorbs electrical and generates chemical energy, the electromotive force required being slightly more than one volt. If the circuit be now opened and the system examined, it will be found to be a source of electrical energy; in other words, a battery, the platinum hydride acting as the anode and the platinum oxide as the cathode in discharging. Its electromotive force will be approximately one volt at the beginning of discharge.

If, instead of interrupting the current when the platinum electrodes have been exhausted by conversion into compounds of platinum with oxygen and hydrogen, we allow the current to continue, an entirely different electrochemical reaction will take place. There being no more platinum to combine with either oxygen or hydrogen, and there being no other substance present at the terminals of the electrolyte capable of undergoing any chemical change under these conditions, the electrolyte itself must decompose in the easiest manner, liberating hydrogen at the cathode and oxygen, hydrogen peroxide or persulphuric acid at the anode.

The electric current, in crossing the junction between an electrode and an electrolyte, must be transmitted by the ions which undergo the electrochemical change. This is equivalent to saying, in the language of current theories, that the ions themselves must receive or give up the electric charges which constitute a current. It is evident, therefore, that these ions on being eliminated from the electrolyte, or on going into the electrolyte, must actually conduct the total current. It is a well-known fact that oxygen and hydrogen in the gaseous state are very perfect *non-conductors*. The resistance of these substances in the gaseous state under ordinary atmospheric pressure is known to be so high that they could not in that state possibly transmit the current of such a cell without opposing a resistance enormously greater than that which has been observed.

The evidence is, therefore, conclusive that these oxygen and hydrogen ions in the particular case under consideration are not rejected at the electrodes in the ordinary gaseous form, for example, as bubbles of gas. This would be impossible, since the total current would have to be transmitted by these bubbles of gas, and not by the surrounding electrolyte. We must conclude, therefore, that these ions are rejected *in solution* as dissolved gases, in which state they may act as conductors, since, owing to their low coefficients of solubility, they would be in a highly-attenuated state, in which condition they are known to be conductors. It is also reasonable to assume that these gases in solution would conduct the current independent of any attenuated state, since many other substances have been found which conduct in solution and do not conduct in the solid or gaseous state. The fact that these products of electrochemical reaction appear as bubbles of gas, and are formed in large quantities, is easily explained, since the elimination of these substances in solution by the current would soon cause supersaturation. The gases would then be spontaneously evolved in the form of bubbles, exactly as carbon dioxide or any other gas is evolved from a supersaturated solution.

In this case, in which oxygen and hydrogen are evolved, it is evident that after these gases have passed out of the solution in the form of bubbles of gas, the chemical energy stored in them cannot be used in a subsequent operation of the apparatus, unless provision is made for collecting the gases and restoring them again to the solution when needed.

This was done by Grove in his celebrated gas battery by inverting closed tubes over the platinum electrodes to collect the evolved gases and retain them in contact with the electrodes and the electrolyte surrounding the electrodes. In this particular case the chemical energy generated in forming the platinum compounds is the only energy available in the subsequent discharge. In discharging this cell, the platinum hydride and platinum oxide are the electrochemical reagents which generate electrical energy in being changed again to platinum and in forming additional molecules of water. But platinum has the property of combining spontaneously at ordinary temperatures with either oxygen or hydrogen on coming in contact with these substances. Therefore, as the platinum hydride and platinum oxide become exhausted in generating electrical energy, the residual platinum in the Grove battery immediately absorbs the surrounding gases, both that in solution adjacent to the platinum surface and that in the reservoir above the solution surrounding the platinum plate. The platinum oxide and platinum hydride are, therefore, spontaneously formed from the stored gases as the discharge proceeds, and this process continues until the gases are exhausted. The oxides and hydrides of platinum formed in this manner are formed thermochemically, however, since the platinum is an actual contact with the gas, and the energy of these combinations is lost as heat. The electrical energy obtainable from the discharge of this cell is therefore less than that required to evolve the gases by the amount of this heat. The electromotive force of the Grove battery is, on this account, only about 1.08 volts, instead of 1.47 volts.

Although every electrochemical reaction is perfectly reversible, the reversibility is not always apparent. Owing to the fact that in most electrochemical systems several reactions take place simultaneously, which are entirely independent of each other and produce different products, an electrochemical system sometimes produces a chemical reaction with the current in one direction, which does not appear to be reversed when the current is in the opposite direction. This apparent irreversibility is due in many cases to the fact that when two or more reactions take place simultaneously at the same point, the reaction which takes place more easily with the current in one direction, reverses most difficulty with the current in the opposite direction.

Another cause of this apparent irreversibility is the mechanical construction of the cell, which is not always such as to preserve the system and retain the products of one reaction in the position required for complete reversal. Another cause which sometimes prevents reversal is the action of selective chemical affinities in the products formed, which may, by secondary reaction, destroy these products.

While all electrochemical reactions are reversible, this does not imply that the process or nature of the electrochemical change is of an opposite kind. The nature of the electrochemical change is always the same.

It is frequently stated that the charging of a storage battery is reversing the process of discharge. The process is exactly

the same in discharging as in charging. The only thing reversed is the electrodes, the cathode becoming the anode and the anode becoming the cathode. In charging a lead accumulator, lead sulphate is changed into lead peroxide at the anode, the electropositive valence of the anode being thereby increased; and simultaneously lead sulphate is reduced to metallic lead at the cathode, its electropositive valence being diminished. In discharging, the reduced electrode becomes the anode, and the lead peroxide electrode becomes the cathode. In this second process, again, the electropositive valence of the lead anode is increased, and the electropositive valence of the lead peroxide cathode is reduced, so that in both cases the electropositive valence of the anode is increased and the electropositive valence of the cathode is reduced. If the discharging reaction is carried to completion, the material is all converted into lead sulphate. If, from this point, the reaction is continued in either the same direction or in the opposite direction, we still continue to have an increase of electropositive valence at the anode and a decrease of electropositive valence at the cathode; but, instead of the formation of lead sulphate from peroxide and metallic lead, we have the formation of peroxide and metallic lead from the sulphate, not because of any reversal of the process, but because we have different materials constituting the electrochemical system. In the beginning of discharge we have a peroxide cathode and a metallic lead anode; at the end of discharge we have a lead sulphate cathode and a lead sulphate anode. If the current is continued now in either direction, we have a system in which the anode is lead sulphate and the cathode lead sulphate. With these electrodes, the current in either direction necessarily produces lead peroxide at the anode and metallic lead at the cathode. We see, therefore, that changing the direction of the current in charging and discharging is not the reversal of an electrochemical process, but must be considered merely a reversal of material used as electrodes and produced as products. In other words, it is the *matter* which undergoes changes and reversals of combination, and not the process. We cannot expect to obtain, when we subject metallic lead to a certain process, the same products as would be obtained by subjecting lead sulphate or lead peroxide to the same process. The process of electrochemical change should always be considered as the same, namely, increase of electropositive valence or decrease of electronegative valence at the anode, and increase of eletronegative valence or decrease of electropositive valence at the cathode. There is no known exception to this statement.

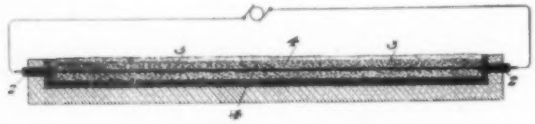
ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

Process of Making Graphite. Edward G. Acheson, Niagara Falls, N. Y. Patent No. 711,031, October 14, 1902. Application filed December 22, 1900.

In this specification Mr. Acheson discloses a new method for the production of graphite from carbonaceous material. Heretofore his process consisted essentially in subjecting carbon, mixed either naturally or artificially with materials capable of forming carbides, to the intense heat of the electric furnace. A perfect transformation of amorphous carbon into graphite may, however, be brought about by causing metallic vapors to act upon the amorphous carbon at the high temperature obtainable in an electric furnace. This may be accomplished by mixing metals or metallic compounds with the charge of carbon, then volatizing the metals or compounds by the intense heat, and thus causing the metallic vapors to permeate the mass of carbon. Various forms of amorphous carbon may be used and various metals or compounds employed for generating metallic vapors, such as iron, silicon, titanium, aluminium, boron or their compounds. The furnace used in the operation is shown in cross section in the adjoining Fig. 1. So-called petroleum



ACHESON GRAPHITE FURNACE.

coke, the residue obtained from the distillation of petroleum oil, is crushed to such a state that its particles vary in size from a powder to lumps 3 to 4 inches in diameter, and is preferably so arranged that the lumps are completely imbedded in the powder. Oxide of iron, in the proportion of 5 pounds of iron to 100 pounds of coke, is roughly mixed with the petroleum coke. The two electrodes 2, 2 are introduced through the ends of the furnace, and carbon rods 3, 3 are arranged between them to serve as preliminary conductors of the current. The entire charge 4 is preferably covered with a layer of material which does not conduct heat, such as sand and powdered carbon in proper proportion to form carbide of silicon. With a furnace 30 feet long, 14 inches wide and 18 inches deep, a current of about 200 volts and 300 ampères is suitable. As the temperature increases, this current rises quickly, on account of the reduced resistance of the carbon rods and the coke. The completion of the furnace operation is indicated by a great reduction of the resistance. During the operation the oxide of iron is reduced to metal, which either is held in the cavities or spaces between the lumps of carbon or drops to the floor of the furnace. Afterwards, as the temperature rises, the metal is volatilized, and, coming into intimate contact with the carbon, effects its conversion into graphite. After the operation the furnace is allowed to cool down, the covering of sand and carbon, which has been partially converted into silicon carbide, is removed and the coke, which has been converted into soft graphite carbon, is taken out. It is interesting to note in this connection that petroleum coke, when treated by Mr. Acheson's earlier method, was considered to graphitize very poorly (J. W. Richards, Electrochemical Industry, Vol. I, page 53). See also an article by Danneel in the *Zeit. f. Elektrochemie*, September 25, 1902, which treats about this subject, and has been abstracted in Electrochemical Industry, Vol. I, page 106.

Object of Refractory Material and Method of Manufacturing Same. Charles B. Jacobs, East Orange, N. J. Patent No. 711,319, October 14, 1902. Application filed December 26, 1900.

According to the inventor, who is connected with the Ampère Electrochemical Co., Niagara Falls, N. Y., this invention has for its object to provide in a commercial form bricks, tiles, blocks or other material of definite shape and of materials such as are not fusible in ordinary furnaces or ovens; for example, the silicates of aluminium and similar refractory silicates. The materials are melted in the electric furnace and cast into molds. It is stated that, in the application of the process to certain materials, such as aluminium silicate, the heat volatilizes a portion of the more volatile constituent (silica), the remaining material being less fusible, harder and tougher than the original material. Fire clay or kaolin is charged into an ordinary furnace, and an arc started between the electrodes and maintained until the mass is fused. In case kaolin or a refractory silicate is being treated, the inventor prefers to continue the heating current for a sufficient time to drive off, in the form of white clouds, a substantial percentage of the silica present in the

material. Thus the kaolin (Al_2O_3, $2SiO_2$) is changed to the normal silicate Al_2O_3, SiO_2. With 200 pounds of material and a current of about 100 volts and 1,500 ampères, it takes about twenty minutes to melt the clay and about forty minutes more to drive off half the silica, so as to leave the normal silicate. This chemical change is accompanied by a very important physical change, namely, an increase of the hardness and toughness and a decrease of the fusibility of the resulting material. If the original material (fire clay) be simply fused and, without the loss of any of its silica, be allowed to cool to solid state, it will present a glossy appearance and be very brittle; but if maintained in a fused state for a sufficient time to lose a substantial or appreciable percentage of its silica, it will cool to a waxy-looking mass of an extreme degree of toughness and hardness. The molten material is poured through a tapping hole in the bottom of the furnace into metal molds. The chilling effect of the metal of the mold causes a thin crust of solidified material to be formed on the surface of the metal, and thus protects the mold from the action of the intensely-heated mass. A material like this would undoubtedly be very valuable for a good many purposes. For ordinary metallurgical uses it might, however, prove to be too expensive, as energy at the rate of 150 kilowatts per hour has to be expended in order to convert 200 pounds of material into the desired product, though the increased cost might be counterbalanced by the increased durability of the material.

Process of Manufacturing Ferrosilicon and Silicospiegel. Gustave Gin, Paris, France. Patent No. 712,925, November 4, 1902. Application filed April 17, 1901.

The process outlined in this specification concerns the manufacture of ferrosilicon and silicospiegel. It is proposed to use as raw material the silicon slags from metallurgical operations in the converters for the Bessemer acid process or in the Martin furnaces with silicon coatings. These slags contain, according to the specification, almost the whole of the elements which are more oxidizable than iron, and especially the metals of the alkaline earths—silicon, titanium and manganese—which existed previously in the ore or have been introduced during the process. It is stated that by regenerating these elements it is possible to obtain from by-products, which are generally worthless, silicides of iron or manganese, "which enable a new cycle of refining operations to be carried on." The specification shows a number of errors in scientific terminology, such, for instance, as the continuous reference to the Martin furnaces with silicon coating, the designation of silicon, titanium and manganese as metals of the alkaline earths; the assertion that the composition of the slag of the acid Bessemer furnaces is silicate 50.82 per cent., alumina 3.15 per cent., etc. At another place it is said: "It has been proposed to extract from the blast furnaces slag carbid of calcium and cast iron, but this use is not in affinity with the particular manufacture of silicides obtained with a particular slag." It is hard to find out what particular idea is meant to be conveyed by this statement. The operation of the process itself is described as follows: "Let it be supposed that the slags to be treated come from the Martin furnaces having acid linings, and that they have the following composition: SiO_2, 50.42; FeO, 34.10; MnO, 9.92; Al_2O_3, 2.25; CaO, etc., 3.30, which may correspond per ton to the following formula: 8,400 SiO (?) + 3,800 FeO + 1,400 MnO + 220 Al_2O_3 + 600 CaO. I add to the slag, which has been pulverized, a quantity of carbon, so that the mixture contains one molecular proportion of carbon for each molecular proportion of oxygen in the silicate (?) and the iron and manganese peroxides without taking care of the alumina and the oxides of alkaline earths. To the slag under consideration it will therefore be necessary to add $8,400 \times 2 + 3,800 + 1,400 = 22,000$ atoms (?) of carbon. This can be done by introducing to the previously pulverized slag the required quantity of coal, etc. The mixture is then subjected to the heat of a continuous or alternating-current electric furnace. The most favorable voltage ranges from 25 to 30 volts, and the power density (the number of volts per square centermetre of the perpendicular cross section of the electrode) should not exceed 70 volts if it be wished to reduce to its lowest practical limit the volatilization of the silicon and the manganese. Under these conditions there are not metallic carbides produced, but a bath of ferrosilicon or silicospiegel is obtained, which is run into ingot molds at intervals. In order that the operation may be carried on continuously, it will suffice to feed the electric furnace regularly with the aforesaid mixture." The derivation of the formula given above is not explained. The slag, metallurgically considered, corresponds very closely to a sesquisilicate, having a ratio of oxygen of the bases to oxygen of the silica of nearly 2 : 3. Consequently its formula would come close to 4RO, $3SiO_2$, designating by RO the monosides FeO, MnO, etc., present in the slag. Mr. Gin has had a great deal of experience in the running of electric furnaces for the manufacture of calcium carbide, and is one of the inventors of one type of them, the Gin & Leleux furnace, and the burden of proof now rests on him to show that he can produce ferrosilicon and silicospiegel economically by this process.

Dentists' Electrical Annealing Furnace. Nathan K. Gerhart, Indianapolis, Ind. Patent No. 712,057, October 28, 1902. Application filed August 22, 1902.

The object is to produce an efficient electric annealing furnace, particularly for the use of dentists. The heat is furnished by electric resistance coils, situated below a heating surface of isinglass or other suitable material. The articles to be heated are laid upon this surface, and are heated by radiation. Various mechanical details of the apparatus are shown, adapting the furnace specially to the use of dentists.

APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

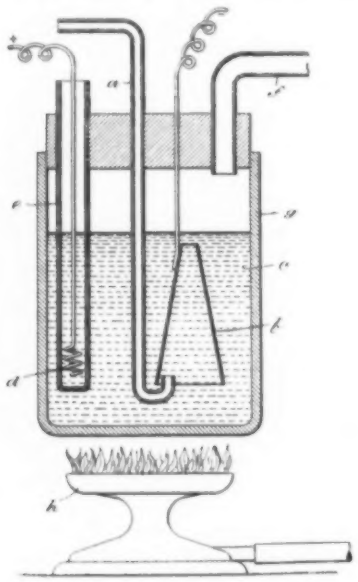
Process of Converting Salt Marsh Material, etc., into a Fertilizer and the Product Resulting Therefrom. J. J. Crooke, New York, N. Y. Patent No. 712,0445, October 28, 1902. Application filed February 21, 1902.

The object is the conversion of the material of the so-called salt marshes or salt meadows into a fertilizer. This material, though it contains a great amount of humus and other compounds which would make it valuable as a fertilizer, cannot be used as such on account of certain acids, as gallic, tannic, acetic or sulphuric acids, and compounds like iron sulphide, sulphuretted and carburetted hydrogen, or an excess of chlorides, being present in it. It is proposed to subject it to electrolytic action in a wooden tank, preferably of rectangular shape, having a capacity of about 5 tons of material, and provided with an electrode at each of its sides, consisting of wrought sheet iron and arranged as a lining to the sides of the tank. The material is charged into the electrolyzer in a wet condition, and subjected to electrolysis for three to five hours. The inventor makes the remarkable statement that hydrogen is given off at the anodes, besides hydrogen sulphide, carburetted hydrogen and chlorine. The current is to be continued until the acid reaction at the anode has become neutral or alkaline. When the operation is completed, the charge is taken out, dried and pulverized, and is then ready to be used as a fertilizer. The invention is said to be applicable not only to the material from salt marshes, but also to that obtained from peat bogs, muck bogs and the dredgings of harbors, bays and the mouths of rivers. Sheet-iron anodes in the presence of chlorine will not last long, and the process seems to involve a considerable expenditure of electrical energy in comparison with the value of the finished material.

Manufacture of Ether. J. W. Harris, Ashbourne, Pa. Patent No. 711,565, October 21, 1902. Application filed June 5, 1902.

The process relates to improvements in the manufacture of ether, which hitherto has been manufactured by mixing alcohol

with sulphuric acid, thus forming ethyl-sulphuric acid, C_2H_5. HSO_4, and then slowly adding more alcohol, which reacts with the ethyl-sulphuric acid according to the equation C_2H_5. HSO_4 + C_2H_5. $OH = C_2H_5$. O. $C_2H_5 + H_2SO_4$. The invention consists in the manufacture of ether directly from acetylene, thus doing entirely away with the use of expensive alcohol. The adjoining figure shows a cross section of the apparatus in which the electrolysis is carried out. It is an ordinary cell *g*, filled with the electrolyte *c* and heated by a burner *h* to the required temperature. The cathode *b* has the shape of a cone, open at its apex, and the spiral anode *d* is surrounded by a tube or porous cell *e*. The acetylene gas enters the tube *a*, bubbles through the electrolyte and passes over the surface of the cathode *b*. The distillate passes off through the tube *f* to a second electrolytic cell, or to others if required. When passing over the cathode, the acetylene is said to combine with the nascent hydrogen liberated by the current to form ethylene and ethane, as expressed by the formula $C_2H_2 + 2H = C_2H_4$. $C_2H_4 + 2H = C_2H_6$. It is important that the production of ethane be restricted as much as possible. The electrolyte, consisting of sulphuric acid containing up to about 35 per cent. of water, is decomposed, the hydrogen acting on the acetylene and the

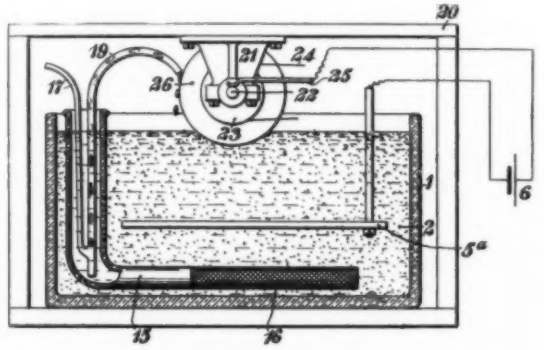


ETHER APPARATUS.

oxygen going to the anode. The ethylene formation takes place in the strong sulphuric acid, and it combines at once with the acid to form ethyl-sulphuric acid, $C_2H_4 + H_2SO_4 = C_2H_5$. HSO_4, which combination takes place preferably at a temperature above 100° C. Water may be supplied to the cell to keep the concentration of the acid constant, or the acetylene gas may be saturated with water before entering the cell. The ethyl-sulphuric acid decomposes into products which vary with the temperature and the quantity of water present. When the water content exceeds 50 per cent., alcohol is generated. As the water content decreases, the per cent. of alcohol decreases, while that of ether begins. The alcohol formation grows less and less as the water content becomes smaller. The other formation continues until the water content is less than 10 per cent. This formation of ether is due to the reaction between two molecules of ethyl-sulphuric acid and one of water, as expressed by the equation $2C_2H_5$. $HSO_4 + H_2O = (C_2H_5)_2O + H_2SO_4$, the electric current assisting this to take place. It is stated that reactions forming alcohol, and subsequently ether, as expressed in the equation (1) C_2H_5. $HSO_4 + H_2O = C_2H_5$. $OH + H_2SO_4$, and (2) C_2H_5. $HSO_4 + C_2H_5$. $OH = (C_2H_5)_2O + H_2SO_4$, may also take place; but that the fact that the formation of alcohol decreases when the water content is less than 50 per cent., while the formation of the ether begins, indicates that the reaction between two molecules of ethyl-sulphuric acid and one of water is the more probable. The object of the porous diaphragm around the anode is to prevent as much as possible the oxidation of the ethyl-sulphuric acid by the oxygen liberated there. The process is an interesteing one, and if it can be carried out successfully on a commercial scale will be another step forward in the application of the electric current in the field of organic chemistry.

Method of and Apparatus for Electrodeposition of Metals. C. J. Reed, Philadelphia, Pa. Patent No. 712,153, October 28, 1902. Application filed August 1, 1901.

The object is to effect the uniform deposition of metals in a hard and compact form, polishing them at the same time. The apparatus is charged with a mixture of a suitable electrolyte and a granular polishing or abrading material, such as sand, for example. The cathode is arranged to be rotated, and thus comes into contact with the abrading material. One form of apparatus, intended for the electroplating of a cylinder, is shown in the adjoining figure, in which 1 is a tank or receptacle charged with the mixture 2 referred to above, and provided with an anode 5a of any suitable shape. The cathode 26 is a cylinder, mounted on a shaft 22, suspended from journals 21 and driven by pulley 23 and belt 24. It is connected by a brush



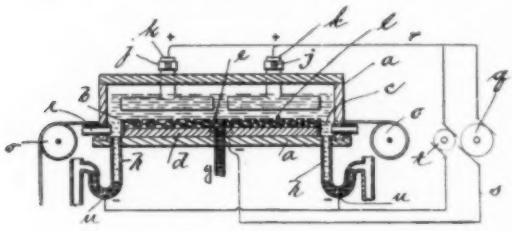
ELECTRODEPOSITION OF METALS.

25 to a suitable source of energy 6. A pipe 15, having a sieve construction 16 at its ends, is arranged on the bottom of the apparatus. Air or gas is supplied under pressure to pipe 17, thus providing effectually for the circulation of the electrolyte. Another apparatus illustrated in the specification shows the same principle applied to the simultaneous electroplating of a large number of small articles, such as tacks, buttons, articles of jewelry, etc.

Electrolytic Cell. A. E. Truesdell, Pittsfield, Mass. Patent No. 712,218, October 28, 1902. Application filed April 13, 1901.

The apparatus belongs to the type of mercury cells for the electrolysis of solutions of salts of the alkali metals. The cell, as shown in cross section in the adjoining diagram, consists of a slate or earthenware vessel *a*, provided with a rib *b* running parallel to each of the longer sides, thus leaving channels *c* between the sides and the side of the vessel. The mercury *e* rests on a floor *d* of cast iron. Anodes *k*, with contact pieces *j*, serve to conduct the current into the solution. For the removal of the amalgam formed by the action of the current, a sweep *l* is provided, which brushes the amalgam over the ribs *b* into the channels *a*, which slope down towards the pipes *h*, in which the amalgam accumulates. The pipe *g* serves to supply the apparatus with fresh mercury from a reservoir, in order to keep the level of the mercury at a certain height. The sweep *l* is moved by means of wires passing over pulleys *o* and introduced into the cell through stuffing boxes. It is said that the

sweep can be dispensed with, and the removal of amalgam be effected by raising the level of the mercury in the reservoir, thus forcing a certain amount of it over the ribs *b* into the channels. It is questionable whether this would have the desired effect in an apparatus large enough to be operated on a commercial scale. The main source of current is located at *g*, but, in order to prevent the discharge of amalgam in the pipes *h*, an auxiliary current is introduced, supplied from *t*, and having its minus pole connected to the amalgam at *u*. It is doubtful, however, whether a reaction of the amalgam with the solvent could be prevented, even by the introduction of a second current, if it is highly charged and stays in the pipe for some time. The admission of fresh electrolyte to the cell takes place through pipes *i*. There is nothing mentioned about the discharge of the amalgam, which evidently has to be accomplished in another apparatus. The means shown for moving the sweep, by wires passing through the electrolyte, suggest more a laboratory scale of operation than a commercial apparatus, as they probably would not last long in an electrolyte charged with chlorine, and by their solution would speedily contaminate the electrolyte.



MERCURY CATHODE CELL.

Electric Refining of Lead and Lead Alloys. A. G. Betts, Lansingburg, N. Y. Patent No. 713,277, November 11, 1902. Application filed January 9, 1902.

The object is to provide a suitable electrolyte for the purpose of electrodepositing lead in a dense and coherent form. The inventor uses as electrolyte a solution proposed by him in a former patent, with the addition of one or more reducing agents. The electrolyte is an acid solution of lead fluo-silicate, and among the reducing agents which he finds available are gelatine, pyrogallol, resoicinol, saligenin, orthoamito phenol, hydroquinone and sulphurous acid. Phenols of the aromatic series are said to be well adapted, by reason of their being easily oxidized. Of the above reducing agents, he has found gelatine to be the cheapest and to give the best results, and prefers to use it in the proportion of one pound of gelatine, by weight, to 5,000 parts of the solution. The gelatine is dissolved in hot water and added to the solution in the desired proportion. The presence of the reducing agent in the solution, it is said, serves to restrain the crystallization of the electrodeposited lead, and causes it to form upon the cathode in a solid body of uniform structure throughout. In this way the formation of short circuits, due to the crystallization of the electrodeposited lead, is obviated, and a product obtained which, by reason of its physical properties, facilitates the practical electrolytic refining operations, and may be fused without the formation of an undue amount of dross. The beneficent effects of the addition of the reducing agents are said to be also visible at the anode, where they preserve the mass of lead underneath the anode slime with a somewhat smoother surface. A plant for the carrying out of the process on a commercial scale, with a capacity of about 10 tons per day, is described by Ulke in the *Engineering and Mining Journal*, October 11, 1902 (see the abstract in ELECTROCHEMICAL INDUSTRY, Vol. I, page 105).

Electrodeposited Lead. A. G. Betts, Lansingburg, N. Y. Patent No. 713,278, November 11, 1902. Application filed October 9, 1902.

This specification is almost identical in phraseology with the preceding one, but claims the product obtained by the process described above. Claim 42 reads: "I claim ..... as a new product, electrodeposited lead characterized by substantial purity, coherency and uniformity of structure throughout, practically free from crystallization and having substantially the homogeneity, with a density of about 11.3, and retaining the normal structural characteristics due to electrolysis."

STORAGE BATTERIES.

Accumulator. Jean Baptiste Relin, Levallois-Perret, France. Patent No. 711,122, October 14, 1902. Application filed December 4, 1901.

The specification describes in detail the construction of a storage-battery plate with the object of obtaining the maximum surface. The plates consist of a frame, usually rectangular, to which are fastened strips of lead rolled up in spiral form, having the shape of a double-spiral wood auger. The spiral slips really form the plate, as the frame serves only to support them. They are flattened down so as to form an indented strip, which is nearly flat, but provided with small projections for retaining the active material and facilitating the circulation of the electrolyte. This flattening down is performed by covering each row over with sea salt or any other substance which is hard but can be easily dissolved out. The strips are then placed in a press and partly compressed, so as to leave projections on their surface. The object of the salt is said to be threefold: to preserve the projections of the strips, to form on their surface a large number of small hollows very suitable for the formation of the active material and to clean the surface of the lead and to make it more sensible to the action of the electrolyte. After putting the plates into water, for the purpose of dissolving the salt, they are subjected to the action of a current in an electrolytic bath for their formation, or they may be filled with active material.

Storage-Battery Plate. N. T. Daboll, New London, Conn. Patent No. 711,481, October 21, 1902. Application filed February 19, 1902.

The object is to construct a plate of reduced weight per unit of electrical energy, and to materially reduce the operations required in forming the plate. The inventor constructs the plate out of wire gauze, coated with finely-divided carbon, and then covered with white lead. The plate is a sort of flat pocket, fashioned out of iron or steel-wire gauze. It is filled with finely-shredded steel, and held together by wires passed through opposite sides, in the manner of tacking a mattress. This structure is then coated with a paste, consisting of finely-divided carbon made into a paste by a watery solution of any hydrocarbon—sugar, for instance—as a binder. This paste is dried, and then carbonized by the action of heat. To complete the plate, the structure is then coated with white lead and allowed to dry. This plate is certainly new, but there may be doubt about its usefulness for practical purposes.

Storage Battery. Frederick Sedgwick, Chicago, Ill. Patent No. 711,537, October 21, 1902. Application filed August 2, 1902.

This patent embodies another attempt at the solution of the problem of obtaining the greatest possible amount of plate surface with the least possible weight of material. The inventor builds up his electrodes from a number of exceedingly thin sheets of lead, about 2-1,000-inch in thickness. In order to provide for the circulation of the electrolyte, these sheets are first prepared by producing on them a large number of small perforations, not less than about 3,600 for each square inch of surface. These perforations are carefully distinguished from mere holes or punctures, and are made by placing the film of lead foil upon the face of a die, provided with fine longitudinal and transverse grooves, between which are projections having minute raised points. A piece of leather is then laid on the foil, and the whole subjected to pressure, thus producing in the foil a uniform series of indentations. The

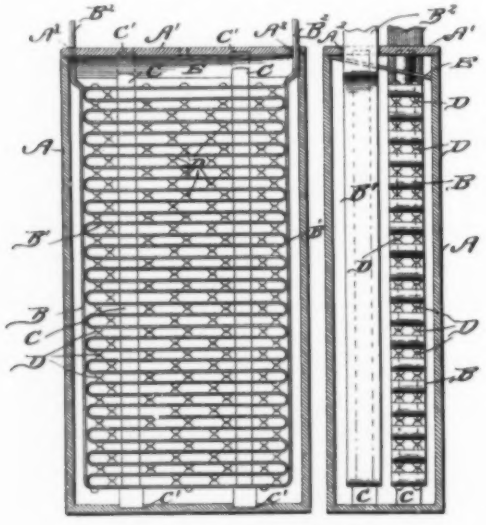
points of these indentations are then planed or filed off, and the foil thus prepared shows a regular series of minute perforations, corresponding to the raised points of the die. The surface is further roughened by means of minute grooves or indentations, and it is claimed that, when the foils are assembled, they form a wick-like cellular mass, through which a free and uniform circulation of the electrolyte may be induced by capillary attraction, allowing the gases to escape as fast as formed. The sheets or films of lead thus prepared are soldered at the top to a lead binding strip, provided with lugs for the necessary connections. Narrow strips of vulcanite or other non-conducting material are inserted between the electrodes to serve as separators and prevent short-circuiting. It seems that, though the object of providing a large amount of plate surface is realized, it was attained by a more or less complicated series of operations, involving the handling of a large number of extremely thin lead foils, with its consequent practical disadvantages.

Storage Battery. Daniel E. Wiseman, Chicago, Ill. Patent No. 711,710, October 21, 1902. Application filed March 12, 1901.

The inventor constructs a plate consisting of one single long and narrow strip of lead, bent back and forth upon itself in serpentine form, as shown in the adjoining figure, where B' represents such a strip. The ends of each bend are soldered to that end of the strip which is intended to form the outside connection. Each strip is provided with a series of hemispherical depressions D, serving to receive the active material and at the same time to hold the bends of the strip in their respective lateral positions. Rods C, C, resting in sockets C'' above and below, are provided to hold the strips in their proper position. The electrodes are arranged side by side, each consisting of one strip.

Storage-Battery Plate. Edward H. Winkes, Buffalo, N. Y. Patent No. 711,917, October 21, 1902. Application filed April 25, 1902.

This patent also relates to an improved form of battery plates, and embodies exactly the same idea as the preceding



STORAGE-BATTERY PLATE.

plate, in so far as a battery plate is made from a single sheet of lead bent in serpentine form, and both inventors propose to keep the folds of the plate separate by hemispherical depressions, as illustrated in the preceding patent. The main difference is that the former inventor bends a thin *strip* or ribbon into serpentine form lengthwise, whereas this one proposes to corrugate a *sheet* of lead sidewise, as it were, so closely that the corrugations are one-thirty-second to one-sixteenth of an inch apart. As the electrolyte could not directly get from one side of the plate to the other in this arrangement, a number of horizontal cuts are made in the plate, through which the circulation can take place. The inventor of the present construction provides a better support for his plates than the one of the preceding patent by mounting them in a bifurcated frame of antimonial lead and soldering the various folds to that frame. He also provides a larger number of the hemispherical depressions, intended to keep the folds separated, and, moreover, roughens the sheets before folding them, and thus furnishes a more suitable seating surface for the active material.

Electric Accumulator. F. Loppé, H. P. Morin, G. J. Griner and D. P. Martin, Paris, France. Patent No. 712,316, October 28, 1902. Application filed October 26, 1899.

In order to obtain a plate combining lightness with large capacity, the inventors construct the electrodes of a number of thin rectangular sheets of lead. Each of these sheets is undulated and perforated with a large number of small holes, forming conical projections, distributed over both faces of the plates. The appearance of the surface is compared to that of a nutmeg grater. A number of these sheets are arranged parallel to each other, and are then folded closely. Space is thus provided between them for the filling in with active material. The coating can either be done by pasting the active material on the sheets at the time the folds are made, or by forming them electrolytically, according to the Planté system. Separators of any insoluble substance are placed between the different electrodes of a cell.

Secondary Battery. Robert Welford, Sunderland, England. Patent No. 713,186, November 11, 1902. Application filed November 21, 1899.

This invention refers to the construction of a battery plate, said to be applicable to the cells of the Planté type, as well as those of the Faure type. In the case of the Faure-type cell, the inventor uses a conducting wire coiled into a helix, and surrounded by active material in such a manner that a wire constitutes the core of a rod or prism of active material. "Thus," says the inventor, "if we imagine a number of candles hanging from a horizontal rod, we obtain a good conception of an elementary form of this invention, it being borne in mind that the tallow corresponds with the paste and that the conductor, coiled or folded, corresponds with the wick." In order to keep these rods apart, a corrugated sheet of hard rubber is employed. The battery plate is constructed by laying a helix of lead wire first on one side into one of the corrugations of the hard-rubber plate, then passing it underneath and up on the other side, twisting the free ends of the wire together on top of the plate. The candles of active material are now prepared by taking a quantity of paste and working it well in and behind the lead wires. If the plate is to be one of the Planté type, he uses an increased quantity of lead wire, coiled, wound or folded into more or less compact form, or places one coil of lead wire into the other. The inventor apparently did not bother about the circulation of the electrolyte.

Storage Battery. Bruce Ford, Philadelphia, Pa. Patent No. 712,999, November 4, 1902. Application filed August 28, 1902.

The battery plate described is provided with strips along each side, these being bent into tubular leads or flanges, which impart the requisite stiffness to the plate, and are also useful as a guide in the application of the active material. Wires may be inserted in the flanges at the corners for the purpose of strengthening them.

Non-Active Metal for Use in Storage Batteries. H. H. Lloyd, Germantown, Pa. Patent No. 713,568, November 11, 1902. Application filed June 29, 1900.

This invention relates to a process of treating antimonial lead, containing about 12 per cent. of antimony, in such a manner that it can be made a suitable material for use in storage

batteries. Antimonial lead has heretofore been used, but the material was brittle, not flexible or resilient, and comparatively heavy in proportion to its mechanical strength, so that it could not be obtained in sheets thin enough for many purposes. The inventor claims to have discovered that such material, after having been cast, can be materially changed in its characteristics by subjecting it to repeated cold rolling or equivalent forging. The effect of the cold rolling upon the cast antimonial lead is to remove it from the class of brittle metals to the class of metals of which sheets of hard rolled copper are a good example. It is stated that the material thus prepared possesses the mechanical strength which is lacking in pure lead, resists the action of acid better than pure lead and cast antimonial lead and is much lighter than either for the same strength.

Supporting and Lifting Mechanism for Secondary Battery Plates. L. H. Flanders, Wilkinsburg, Pa. Patent No. 711,488, October 21, 1902. Application filed February 24, 1902.

The invention relates to means for supporting the electrodes of secondary batteries in the tanks, and for lifting the plates from the tanks for cleaning or repairs. The plates are provided on each side with a projecting lug, resting upon a bar or beam of plate glass or other insulating material, which in their turn find their support in recesses provided at each corner of the receptacle. The lifting is done by simple mechanical means.

Separator for Storage-Battery Plates. Rufus N. Chamberlain, Depew, N. Y. Patent No. 712,178, October 28, 1902. Application filed May 13, 1901.

The specification describes a new form of separator, which also prevents short circuits at the edges of the plates, caused by the dropping off of active material. It consists of a flat, perforated plate of hard rubber or other impervious material, which is provided with flanges along its upright edges. Each positive electrode is inclosed by a pair of separators, the side flanges of the separators inclosing the upright side edges of the electrode. The separators are further provided with spring ribs or projections, bearing against the electrodes and serving to keep the separators a little distance away from them.

Battery Installation for Submarine Boats. S. Lake, Bridgeport, Conn. Patent No. 712,814, November 4, 1902. Application filed March 4, 1902.

This invention has for its object to provide a storage-battery installation system for submarine boats, which shall be compact, shall insure a thorough insulation between the several battery cells and their permanent relative disposition within the hull, and shall effectually prevent the escape of the battery fumes and gases into the adjacent portions of the boat. To this end, the inventor uses a special construction of air and gas-tight compartment for inclosing the system of storage-battery cells, and a composite water-proof insulating lining for this compartment, a water-proof and non-conducting cement filling intermediate the several battery cells and the side walls. The construction is described in detail.

Process of Forming Electric Accumulators. W. Morrison, Chicago, Ill. Patent No. 711,997, October 28, 1902. Application filed March 18, 1901.

The specification describes an electrolytic process for the rapid disintegration of storage-battery plates, preparatory to their formation. The electrolyte proposed is hydrofluoric acid, or any of the soluble fluorides in a solution containing any of the chlorates, nitrates or similar compounds of a highly oxydizing nature capable of acting with the fluorides. Non-oxydizing agents, as acetic acid, may also be successfully used in solution with a soluble fluoride and a suitable "excitant." When the hydrofluoric acid or other soluble fluoride is placed in a solution containing nitrates, chlorates or a combination of them or similar compounds, by which fluorine gas is liberated by the action of the electric current and in combination with the other gases, the fluorine and other gases will attack the plate, producing a disintegrated material, strongly adhering to its support and throughout its mass. This material is afterward to be converted into an oxide of lead or spongy lead. If the fluorides are not used in the electrolyte, this mass will not possess the highly desirable adhesive qualities described. Special stress is laid on the assertion that nitrates, chlorates, etc., in solution with sulphuric acid, etc., do not produce sufficiently cohesive material for practical purposes. The plates to be treated are introduced into an electrolyte, as described, and used as anodes; lead plates being used as cathodes. Afterwards the plates are placed in a solution of sulphuric acid and water. It is said that, in order to hasten the process, this solution may contain zinc or any other metal capable of being deposited on the plate. This is supposed to be dissolved by the sulphuric acid and to produce nascent hydrogen, whereby spongy lead is produced on the plate. It is stated that other reducing agents, as which are named tartaric and oxalic acids, can be added to the solution in order to assist the reduction and to more completely reduce the disintegrated structure to spongy lead in a shorter time.

Process of Peroxydizing Storage-Battery Plates. R. N. Chamberlain, Depew, N. Y. Patent No. 712,995, November 4, 1902. Application filed August 23, 1900.

The invention refers to an improvement on the process of peroxydizing storage-battery plates. According to the inventor, the solution used up to now as an electrolyte consisted of sulphuric acid, to which a certain proportion of alkaline nitrates or a small amount of nitric acid were added. The first method is said to leave a certain amount of soluble alkaline sulphates in the bath, which are apt to lead to injurious secondary reactions; while the second method is said to have the disadvantage that the nitric acid, not being set free in the bath in a nascent state, is not as energetic as it would be if it were nascent. It is proposed to remedy these defects by adding to the sulphuric acid solution a suitable proportion of the nitrate of a metal whose sulphate is substantially insoluble in the bath—for example, nitrate of lead. The plates are first placed in a pickling solution, composed of dilute nitric acid, and are then transferred to a bath containing a solution of sulphuric acid, of 36.7 parts of H_2SO_4 to every 100 parts of water. To this are added 16 parts of nitrate of lead. The plates to be peroxydized are connected as anodes in this bath, preferably before the addition of the nitrate of lead. Upon electrolysis, lead nitrate is formed at the anode, which is immediately converted into sulphate, adhering to the anode. This is gradually converted by the oxygen into peroxide of lead. On addition of lead nitrate to the solution, lead sulphate is, of course, precipitated, and new nitrate of lead is added from time to time to maintain the efficiency of the bath. The precipitated sulphate which accumulates in the bath, is removed from time to time. After the plates have received a sufficient coating of peroxide, they are taken out of the bath, washed and put in the ordinary forming bath, where they are electrolyzed till all the sulphate of lead remaining on them has been cleaned off.

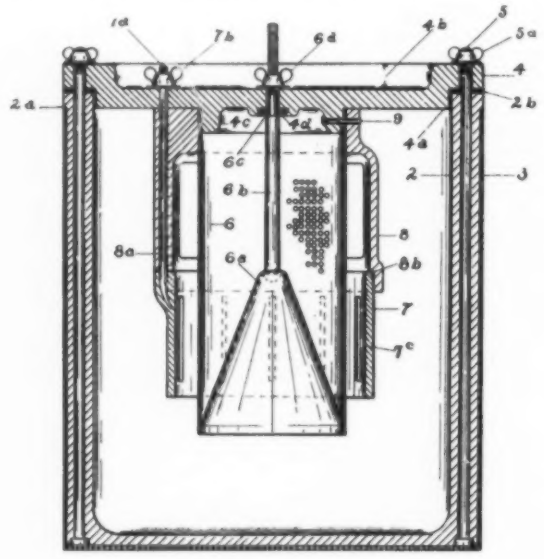
GALVANIC CELLS.

Gravity Battery. W. N. Gore, Philadelphia, Pa. Patent No. 712,668, November 4, 1902. Application filed January 16, 1902.

The invention applies particularly to gravity cells, like the ordinary crow-foot cell, and consists in replacing the copper electrode used in this type of cells by one composed of Babbitt metal. The inventor claims that by this substitution the strength of the battery is materially increased, and that one cell containing Babbitt metal as one of the electrodes is equal in strength to two cells in which copper is used in series. The e. m. f. of the crow-foot cell is about .98 volt, and the cell under consideration is stated to have an e. m. f. of 1.2 volts. Claim No. 1 covers broadly the use of Babbitt metal as an element of any battery.

Voltaic Cells. Herbert B. Taylor, Newark, N. J. Patent No. 713,174. November 11, 1902. Application filed April 2, 1902.

The specification describes a new form of battery of the zinc-copperoxide type, belonging to the class of water-tight cells, and primarily designed for use on boats or automobiles.



ZINC-COPPEROXIDE CELL.

Its construction can be seen from the accompanying figure. Here 2 represents the jar, preferably of hard fibre, covered on the outside with a metal jacket 3. From the cover is suspended a separator or insulator 8, of the same material as the jar and cover, serving to support the positive zinc electrode. There is also suspended from the cover a so-called "container" 6, preferably of perforated metal. The bottom of the container is formed by the negative electrode 6a, of copper, in the shape of a cone, on which rests the material used as a depolarizer, small cakes or pellets of cupric oxide being preferably used in this instance. It will be seen from the figure that the cell can be quickly taken apart and repaired if necessary.

Electric Battery. Albert J. Cook, Jersey City, N. J. Patent No. 710,953. October 14, 1902. Application filed July 20, 1901.

The specification describes at length a new form of cell, constructed with a view of obtaining as large an electrode surface for a given space as possible, and facilitating charging and repairs. One electrode is made in one piece of rectangular cross section, and divided into four compartments, each being of triangular shape. Porous cups, also of triangular shape, are inserted into these compartments and the opposite electrodes, four in number, and also of triangular shape, are introduced into the porous cups. A system of ribs on the bottom of the containing vessel, into which the various parts fit, serve to keep them in position. The cover is made fluid-tight. The cell is evidently designed for use on automobiles.

Tank. Hugh Bradshaw, Chicago, Ill. Patent No. 711,465. October 21, 1902. Application filed June 13, 1902.

The invention "relates to a form of tank adapted to be sunk into the ground for the purpose of inclosing and protecting various devices from freezing." For example, in railway signaling systems it is the practice to employ batteries for operating the various devices of the system, and it is highly desirable that these batteries be protected against weather attacks, and particularly against freezing. A tank is shown in the specification, embodying several devices to prevent cold air from getting into the interior.

MISCELLANEOUS.

Process of Framing Glass or other Materials. H. W. Scattergood, Philadelphia, Pa. Patent No. 709,513. September 23, 1902. Application filed June 19, 1902.

The process consists in sticking the various pieces of glass, arranged in the desired design, on a sheet of thin paper, leaving uniform spaces between the respective pieces. This is then transferred to a board, a frame of wood is put around it and the spaces are filled with starch or cream of tartar, after which the whole is covered with sand to the top of the mold. Another board is then put on top, clamped to the first, and the object is reversed. The first board is then removed, the paper stripped off and the starch or other material in the spaces metallized by the application of metal powder. Another frame is then put on top of the first one; the back of the object, with the exposed metallization, is painted over with fluid wax or any other adhesive, and the whole second frame is then filled with molten wax, which will solidify and form a backing for the object during the remainder of the process. The frames are then removed, the sand cleaned off and the starch filling in the spaces taken out, thus leaving the design, with the metallized spaces between, in such shape that it can be put into the electrolytic bath. The metallization of the spaces constitutes the cathodes, upon which the metal is deposited.

THE ELECTRICITY BUILDING OF THE UNIVERSAL EXPOSITION OF ST. LOUIS, U. S. A., 1904.

The Electricity Building of the Universal Exposition of St. Louis, 1904, is the largest ever provided, by an exposition or otherwise, for electrical exhibits and displays. It covers virtually 300,000 square feet of ground space, as against 250,000 covered by the Electricity Building at the Columbian Exposition, at Chicago, in 1893, and 75,000 by the Electricity Building at the Pan-American, at Buffalo, in 1901. It is of most graceful design and proportions, forming an elaborate pentagon, each of its five sides presenting a succession of splendid columns after the richest Corinthian order, four sides being surrounded by a balcony of rare grace and beauty. It incloses an open central circular court, surrounded by rich colonnades, which will be banked with masses of flowers and make a pleasing retreat for visitors to the building.

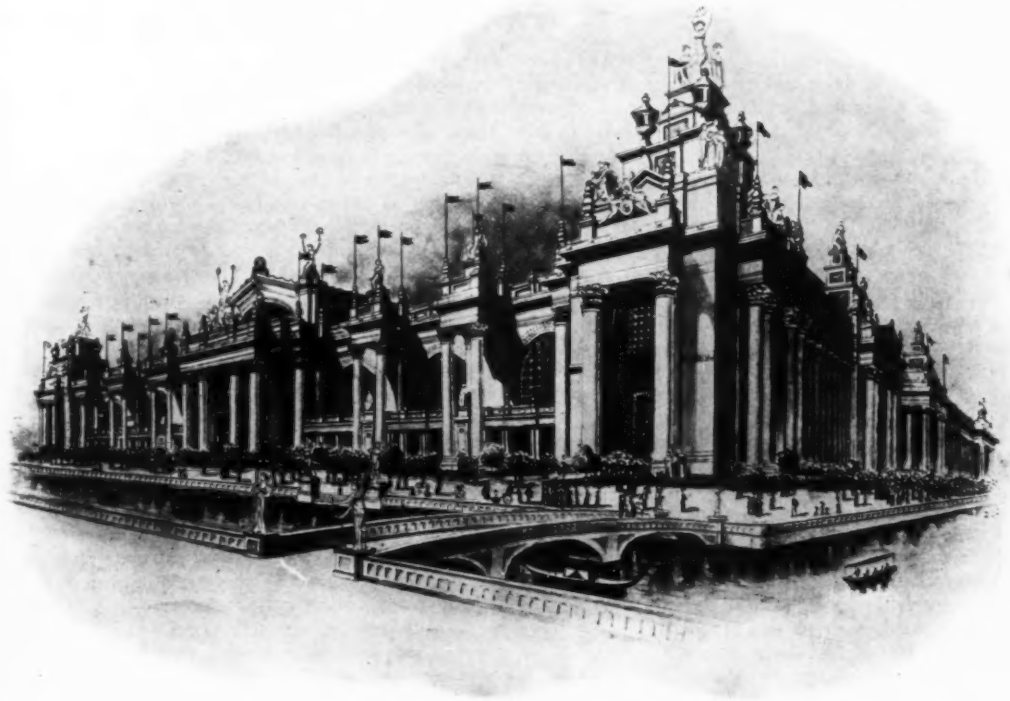
Its location within the exposition grounds is most favorable. It rises right at the foot of the grand terrace and cascades, and thus constitutes a prominent feature of the main arrangement of the rich section, which is called the main picture of the exposition. The eastern exposure of the building fronts 525 feet on the main avenue of the exposition. This broad thoroughfare leads up from the main entrance to the grand basin and cascades, and is penetrated by the central lagoon. The southern exposure, facing the grand basin and the cascades, is in direct view of the electric fountains, the peristyle of the Festival Hall and the splendid Fine Arts palaces. On the west and north the building is bordered by other principal avenues of the exposition and additional extended arms of the lagoon. It is therefore completely surrounded by water. It is led up to by splendid arch bridges, which will discharge the crowds into the broad avenues directly surrounding the building. Four main entrances are provided, one imposing portal at the meeting of the two north facades and one at the center of each of the other sides. Graceful and ample entrances are also provided at the corners of the building. The doors are of gigantic dimensions, 11 x 18 feet. The north facades of the building measure 600 feet, which makes its greater dimensions 525 x 600 feet; 176 trusses and 185 tons of steel have been used in its construction.

The details of the building are well executed in every respect. The fenestration is bold, liberal and appropriate, giving ample light, while affording substantial wall treatment. On two sides graceful and capacious loggias have been extended, which enhance the general beauty of the facades, offering pleasing

effects of light and shadow. A rare scheme of indirect illumination is being worked out, and will be applied to the building, which will accentuate its beauty at night.

The design of the building and its general and special proportions and arrangement are peculiarly adapted for an effective display of exhibits. There are numerous openings in the facades, such as exhibitors seek in selecting their exhibit spaces. Each of the 300,000 feet of floor space is directly available. It is all ground-floor space, there being not a foot of gallery space in the building, nor in any other exhibit building of the exposition, a feature of the Electricity Building and of the Universal Exposition that will be welcomed and appreciated by exhibitors and public alike.

A great traveling crane, to be used in the placing of the heavy electrical machinery which is to be exhibited, will be installed in the building, and all other conveniences afforded to exhibitors in locating and placing their exhibits.



ELECTRICITY BUILDING, SAINT LOUIS EXPOSITION.

In the Electricity Building, those electrochemical exhibits will be placed which show electrochemical processes in operation. This is in agreement with the general idea of the director of the electrical department of the exhibition, Prof. W. E. Goldsborough, to make the Electricity Building not a museum of finished products, but to make it full of life, to show how the products are made and how the processes are being worked. In this way it is hoped that the Electricity Building will become extremely attractive to the general public, who wish to see "something doing," and it is to be hoped that the electrochemical manufacturers will use this opportunity to win the interest and good-will of the general public by exhibiting model plants.

ERRATUM.—In our November issue, page 102, second column, line 13 from the bottom, there is a typographical error. The sentence should read: "Hydrogen (in combination) has always one positive bond." In the numerical applications in the same article this rule is correctly applied throughout, so that we trust our readers have already corrected the misprint.

LOW TEMPERATURE RESEARCHES.*

BY JAMES DEWAR,

President of the British Association for the Advancement of Science.

[*Concluded from page 91*]

The strong condensing powers of liquid hydrogen afford a simple means of producing vacua of very high tenuity. When one end of a sealed tube containing ordinary air is placed for a short time in the liquid, the contained air accumulates as a solid at the bottom, while the higher part is almost entirely deprived of particles of gas. So perfect is the vacuum thus formed that the electric discharge can be made to pass only with the greatest difficulty. Another important application of liquid air, liquid hydrogen, etc., is as analytic agents. Thus, if a gaseous mixture be cooled by means of liquid oxygen, only those constituents will be left in the gaseous state which are less condensable than oxygen. Similarly, if this gaseous residue be in its turn cooled in liquid hydrogen, a still further separation will be effected, everything that is less volatile than hydrogen being condensed to a liquid or solid. By proceeding in this fashion, it has been found possible to isolate helium from a mixture in which it is present to the extent of only one part in 1,000. By the evaporation of solid hydrogen under the air pump we can reach within 13 or 14 degrees of the zero, but there or thereabouts our progress is barred. This gap of 13 degrees might seem at first sight insignificant in comparison with the hundreds that have already been conquered. But to win one degree low down the scale is quite a different matter from doing so at higher temperatures. In fact, to annihilate these few remaining degrees would be a far greater achievement than any so far accomplished in low-temperature research.

For the difficulty is twofold, having to do partly with process and partly with material. The application of the methods used

* Presidential Address, to the British Association for the Advancement of Science. (On account of lack of space the chapter on the upper air and auroras, in the latter part of the address, had to be omitted. Otherwise the address is printed nearly in full.—Ed.)

in the liquefaction of gases becomes continually harder and more troublesome as the working temperature is reduced. Thus, to pass from liquid air to liquid hydrogen—a difference of 60 degrees—is, from a thermodynamic point of view, as difficult as to bridge the gap of 150 degrees that separates liquid chlorine and liquid air. By the use of a new liquid gas exceeding hydrogen in volatility to the same extent as hydrogen does nitrogen, the investigator might get to within 5 degrees of the zero. But even a second hypothetical substance, again exceeding the first one in volatility to an equal extent, would not suffice to bring him quite to the point of his ambition. That the zero will ever be reached by man is extremely improbable.

A thermometer introduced into regions outside the uttermost confines of the earth's temperature might approach the absolute zero, provided that its parts were highly transparent to all kinds of radiation, otherwise it would be affected by the radiation of the sun, and would therefore become heated. But supposing all difficulties to be overcome, and the experimenter to be able to reach within a few degrees of the zero, it is by no means certain that he would find the near approach of the death of matter sometimes pictured. Any forecast of the phenomena that would be seen must be based on the assumption that there is continuity between the processes studied at attainable temperatures and those which take place at still lower ones. Is such an assumption justified? It is true that many changes in the properties of substances have been found to vary steadily with the degree of cold to which they are exposed. But it would be rash to take for granted that the changes which have been traced in explored regions continue to the same extent and in the same direction as those which are as yet unexplored. Of such a breakdown low-temperature research has already yielded a direct proof, at least in one case. A series of experiments with pure metals showed that their electrical resistance gradually decreases as they are cooled to lower and lower temperatures, in such ratio that it appeared probable that at the zero of absolute temperature they would have no resistance at all and would become perfect conductors of electricity. This was the inference that seemed justifiable by observations taken at depths of cold which can be obtained by means of liquid air and less powerful refrigerants. But with the advent of the more powerful refrigerant, liquid hydrogen, it became necessary to revise that conclusion. A discrepancy was first observed when a platinum resistance thermometer was used to ascertain the temperature of that liquid boiling under atmospheric and reduced pressure. All known liquids, when forced to evaporate quickly, by being placed in the exhausted receiver of an air pump, undergo a reduction in temperature, but when hydrogen was treated in this way it appeared to be an exception. The resistance thermometer showed no such reduction as was expected, and it became a question whether it was the hydrogen or the thermometer that was behaving abnormally. Ultimately, by the adoption of other thermometrical appliances, the temperature of the hydrogen was proved to be lowered by exhaustion, as theory indicated. Hence, it was the platinum thermometer which had broken down. In other words, the electrical resistance of the metal employed in its construction was not, at temperatures about *minus* 250° C., decreased by cold in the same proportion as at temperatures about *minus* 200°. This being the case, there is no longer any reason to suppose that at the absolute zero platinum would become a perfect conductor of electricity; and in view of the similarity between the behavior of platinum and that of other pure metals in respect of temperature and conductivity, the presumption is that the same is true of them also. At any rate, the knowledge, that in the case of at least one property of matter we have succeeded in attaining a depth of cold sufficient to bring about unexpected change in the law expressing the variation of that property with temperature, is sufficient to show the necessity for extreme caution in extending our inferences regarding the properties of matter near the zero of temperature. Lord Kelvin evidently anticipates the possibility of more remarkable electrical properties being met with in the metals near the zero. A theoretical investigation on the relation of "electrions" and atoms has led him to suggest a hypothetical metal having the following remarkable properties: Below 1 degree absolute it is a perfect insulator of electricity; at 2 degrees it shows noticeable conductivity, and at 6 degrees it possesses high conductivity. It may safely be predicted that liquid hydrogen will be the means by which many obscure problems of physics and chemistry will ultimately be solved, so that the liquefaction of the last of the old permanent gases is as pregnant now with future consequences of great scientific moment, as was the liquefaction of chlorine in the early years of the last century.

The next step towards the absolute zero is to find another gas more volatile than hydrogen, and that we possess in the gas occurring in clevite, identified by Ramsay as helium, a gas which is widely distributed, like hydrogen, in the sun, stars and nebulæ. A specimen of this gas was subjected by Olszewski to liquid air temperatures, combined with compression and subsequent expansion, following the Cailletet method, and resulted in his being unable to discover any appearance of liquefaction, even in the form of mist. His experiments led him to infer that the boiling point of the substance is probably below 9 degrees absolute. After Lord Rayleigh had found a new source of helium in the gases which are derived from the Bath springs, and liquid hydrogen became available as a cooling agent, a specimen of helium cooled in liquid hydrogen showed the formation of fluid, but this turned out to be owing to the presence of an unknown admixture of other gases. As a matter of fact, a year before the date of this experiment I had recorded indications of the presence of unknown gases in the spectrum of helium derived from this source. When subsequently such condensable constituents were removed, the purified helium showed no signs of liquefaction, even when compressed to 80 atmospheres, while the tube containing it was surrounded with solid hydrogen. Further, on suddenly expanding, no instantaneous mist appeared. Thus helium was definitely proved to be a much more volatile substance than hydrogen, in either the liquid or solid condition. The inference to be drawn from the adiabatic expansion effected under the circumstances is that helium must have touched a temperature of from 9 to 10 degrees for a short time without showing any signs of liquefaction, and consequently that the critical point must be still lower. This would force us to anticipate that the boiling point of the liquid will be about 5 degrees absolute, or liquid helium will be four times more volatile than liquid hydrogen, just as liquid hydrogen is four times more volatile than liquid air. Although the liquefaction of the gas is a problem for the future, this does not prevent us from safely anticipating some of the properties of the fluid body. It would be twice as dense as liquid hydrogen, with a critical pressure of only 4 or 5 atmospheres. The liquid would possess a very feeble surface tension, and its compressibility and expansibility would be about four times that of liquid hydrogen, while the heat required to vaporize the molecule would be about one-fourth that of liquid hydrogen. Heating the liquid 1 degree above its boiling point would raise the pressure by 1¾ atmospheres, which is more than four times the increment for liquid hydrogen. The liquid would be only 17 times denser than its vapor, whereas liquid hydrogen is 65 times denser than the gas it gives off. Only some 3 or 4 degrees would separate the critical temperature from the boiling point and the melting point, whereas in liquid hydrogen the separation is respectively 10 and 15 degrees. As the liquid refractivities for oxygen, nitrogen and hydrogen are closely proportional to the gaseous values, and as Lord Rayleigh has shown that helium has only one-fourth the refractivity of hydrogen, although it is twice as dense, we must infer that the refractivity of liquid helium would also be about one-fourth that of liquid hydrogen. Now, hydrogen has the smallest refractivity of any known liquid, and yet liquid helium will have only about one-fourth of this value —comparable, in fact, with liquid hydrogen just below its

critical point. This means that the liquid will be quite exceptional in its optical properties, and very difficult to see. This may be the explanation of why no mist has been seen on its adiabatic expansion from the lowest temperatures. Taking all these remarkable properties of the liquid into consideration, one is afraid to predict that we are at present able to cope with the difficulties involved in its production and collection. Provided the critical point is, however, not below 8 degrees absolute, then from the knowledge of the conditions that are successful in producing a change of state in hydrogen through the use of liquid air, we may safely predict that helium can be liquefied by following similar methods. If, however, the critical point is as low as 6 degrees absolute, then it would be almost hopeless to anticipate success by adopting the process that works so well with hydrogen. The present anticipation is that the gas will succumb after being subjected to this process, only, instead of liquid air under exhaustion being used as the primary cooling agent, liquid hydrogen evaporating under similar circumstances must be employed. In this case the resulting liquid would require to be collected in a vacuum vessel, the outer walls of which are immersed in liquid hydrogen. The practical difficulties and the cost of the operation will be very great, but, on the other hand, the descent to a temperature within 5 degrees of the zero would open out new vistas of scientific inquiry, which would add immensely to our knowledge of the properties of matter. To command in our laboratories a temperature which would be equivalent to that which a comet might reach at an infinite distance from the sun would indeed be a great triumph for science. If the present Royal Institution attack on helium should fail, then we must ultimately succeed by adopting a process based on the mechanical production of cold through the performance of external work. When a turbine can be worked by compressed helium, the whole of the mechanism and circuits being kept surrounded by liquid hydrogen, then we need hardly doubt that the liquefaction will be effected. In all probability gases other than helium will be discovered of greater volatility than hydrogen. It was at the British Association meeting in 1896 that I made the first suggestion of the probable existence of an unknown element which would be found to fill up the gap between argon and helium, and this anticipation was soon taken up by others and ultimately confirmed. Later, in the Bakerian Lecture for 1901, I was led to infer that another member of the helium group might exist having the atomic weight about 2, and this would give us a gas still more volatile, with which the absolute zero might be still more nearly approached. It is to be hoped that some such element or elements may yet be isolated and identified as coronium or nebulium. If amongst the unknown gases possessing a very low critical point some have a high critical pressure, instead of a low one, which ordinary experience would lead us to anticipate, then such difficultly liquefiable gases would produce fluids having different physical properties from any of those with which we are acquainted. Again, gases may exist having smaller atomic weights and densities than hydrogen, yet all such gases must, according to our present views of the gaseous state, be capable of liquefaction before the zero of temperature is reached. The chemists of the future will find ample scope for investigation within the apparently limited range of temperature which separates solid hydrogen from the zero. Indeed, great as is the sentimental interest attached to the liquefaction of these refractory gases, the importance of the achievement lies rather in the fact that it opens out new fields of research and enormously widens the horizon of physical science, enabling the natural philosopher to study the properties and behavior of matter under entirely novel conditions. This department of inquiry is as yet only in its infancy, but speedy and extensive developments may be looked for, since within recent years several special cryogenic laboratories have been established for the prosecution of such researches, and a liquid-air plant is becoming a common adjunct to the equipment of the ordinary laboratory.

VARIOUS LOW-TEMPERATURE RESEARCHES.

We may now summarize some of the results which have already been attained by low-temperature studies. In the first place, the great majority of chemical interactions are entirely suspended, but an element of such exceptional powers of combination as fluorine is still active at the temperature of liquid air. Whether solid fluorine and liquid hydrogen would interact, no one can at present say. Bodies naturally become denser, but even a highly expansive substance, like ice, does not appear to reach the density of water at the lowest temperature. This is confirmatory of the view that the particles of matter under such conditions are not packed in the closest possible way. The force of cohesion is greatly increased at low temperatures, as is shown by the additional stress required to rupture metallic wires. This fact is of interest in connection with two conflicting theories of matter. Lord Kelvin's view is that the forces that hold together the particles of bodies may be accounted for without assuming any other agency than gravitation or any other law than the Newtonian. An opposite view is that the phenomena of the aggregation of molecules depend upon the molecular vibration as a physical cause. Hence, at the zero of absolute temperature, this vibrating energy being in complete abeyance, the phenomena of cohesion should cease to exist, and matter generally be reduced to an incoherent heap of cosmic dust. This second view receives no support from experiment.

The photographic action of light is diminished at the temperature of liquid air to about 20 per cent. of its ordinary efficiency, and at the still lower temperature of liquid hydrogen only about 10 per cent. of the original sensitivity remains. At the temperature of liquid air or liquid hydrogen, a large range of organic bodies, and many inorganic ones, acquire under exposure to violet light the property of phosphorescence. Such bodies glow faintly so long as they are kept cold, but become exceedingly brilliant during the period when the temperature is rising. Even solid air is a phosphorescent body. All the alkaline earth sulphides which phosphoresce brilliantly at the ordinary temperature lose this property when cooled, to be revived on heating; but such bodies in the first instance may be stimulated through the absorption of light at the lowest temperatures. Radio-active bodies, on the other hand, like radium, which are naturally self-luminous, maintain this luminosity unimpaired at the very lowest temperatures, and are still capable of inducing phosphorescence in bodies like the platino-cyanides. Some crystals become for a time self-luminous when cooled in liquid air or hydrogen, owing to the induced electric stimulation causing discharges between the crystal molecules. This phenomenon is very pronounced with nitrate of uranium and some platino-cyanides.

In conjunction with Professor Fleming, a long series of experiments were made on the electric and magnetic properties of bodies at low temperatures. The subjects that have been under investigation may be classified as follows: "The Thermo-Electric Powers of Pure Metals," "The Magnetic Properties of Iron and Steel," "Dielectric Constants," "The Magnetic and Electric Constants of Liquid Oxygen," "Magnetic Susceptibility."

The investigations have shown that electric conductivity in pure metals varies almost inversely as the absolute temperature down to *minus* 200 degrees, but that this law is greatly affected by the presence of the most minute amount of impurity. Hence the results amount to a proof that electric resistance in pure metals is closely dependent upon the molecular or atomic motion which gives rise to temperature, and that the process by which the energy constituting what is called an electric current is dissipated essentially depends upon non-homogeneity of structure and upon the absolute temperature of the material. It might be inferred that at the zero of absolute temperature resistance would vanish altogether, and all pure metals become perfect conductors of electricity. This conclusion, however, has been rendered very doubtful by

subsequent observations made at still lower temperatures, which appear to point to an ultimate finite resistance. Thus the temperature at which copper was assumed to have no resistance was *minus* 223 degrees, but that metal has been cooled to *minus* 253 degrees without getting rid of all resistance. The reduction in resistance of some of the metals at the boiling point of hydrogen is very remarkable. Thus copper has only 1 per cent., gold and platinum 3 per cent. and silver 4 per cent. of the resistance they possessed at zero C., but iron still retains 12 per cent. of its initial resistance. In the case of alloys and impure metals, cold brings about a much smaller decrease in resistivity, and in the case of carbon and insulators like gutta-percha, glass, ebonite, etc., their resistivity steadily increases. The enormous increase in resistance of bismuth, when transversely magnetized and cooled, was also discovered in the course of these experiments. The study of dielectric constants at low temperatures has resulted in the discovery of some interesting facts. A fundamental deduction from Maxwell's theory is that the square of the refractive index of a body should be the same number as its dielectric constant. So far, however, from this being the case generally, the exceptions are far more numerous than the coincidences. It has been shown in the case of many substances, such as ice and glass, that an increase in the frequency of the alternating electromotive force results in a reduction of the dielectric constant to a value more consistent with Maxwell's law. By experiments upon many substances, it is shown that even a moderate increase of frequency brings the large dielectric constant to values quite near to that required by Maxwell's law. It was thus shown that low temperature has the same effect as high frequency in annulling the abnormal dielectric values. The exact measurement of the dielectric constant of liquid oxygen, as well as its magnetic permeability, combined with the optical determination of the refractive index, showed that liquid oxygen strictly obeys Maxwell's electro-optic law even at very low electric frequencies. In magnetic work the result of greatest value is the proof that magnetic susceptibility varies inversely as the absolute temperature. This shows that the magnetization of paramagnetic bodies is an affair of orientation of molecules, and it suggests that at the absolute zero all the feebly paramagnetic bodies will be strongly magnetic. The diamagnetism of bismuth was found to be increased at low temperatures. The magnetic moment of a steel magnet is temporarily increased by cooling in liquid air, but the increase seems to have reached a limit, because on further cooling to the temperature of liquid hydrogen hardly any further change was observed. The study of the thermo-electric relations of the metals at low temperatures resulted in a great extension of the well-known Tait thermo-electric diagram. Tait found that the thermo-electric power of the metals could be expressed by a linear function of the absolute temperature, but at the extreme range of temperature now under consideration this law was found not to hold generally; and, further, it appeared that many abrupt electric changes take place, which originate probably from specific molecular changes occurring in the metal. The thermo-electric neutral points of certain metals, such as lead and gold, which are located about or below the boiling point of hydrogen, have been found to be a convenient means of defining specific temperatures in this exceptional part of the scale.

The effect of cold upon the life of living organisms is a matter of great intrinsic interest, as well as of wide theoretical importance. Experiment indicates that moderately high temperatures are much more fatal, at least to the lower forms of life, than are exceedingly low ones. Professor McKendrick froze for an hour at a temperature of 182° C. samples of meat, milk, etc., in sealed tubes; when these were opened, after being kept at blood heat for a few days, their contents were found to be quite putrid. More recently some more elaborate tests were carried out at the Jenner Institute of Preventive Medicine on a series of typical bacteria. These were exposed to the temperature of liquid air for twenty hours, but their vitality was not affected, their functional activities remained unimpaired, and the cultures which they yielded were normal in every respect. The same result was obtained when liquid hydrogen was substituted for air. A similar persistence of life in seeds has been demonstrated even at the lowest temperatures; they were frozen for over a hundred hours in liquid air, at the instance of Messrs. Brown and Escombe, with no other result than to affect their protoplasm with a certain inertness, from which it recovered with warmth. Subsequently commercial samples of barley, pea, vegetable marrow and mustard seeds were literally steeped for six hours in liquid hydrogen at the Royal Institution, yet when they were sown by Sir W. T. Thiselton Dyer at Kew, in the ordinary way, the proportion in which germination occurred was no less than in the other batches of the same seeds which had suffered no abnormal treatment. Bacteria are minute vegetable cells, the standard of measurement for which is the "mikron." Yet it has been found possible to completely triturate these microscopic cells when the operation is carried out at the temperature of liquid air, the cells then being frozen into hard, breakable masses. The typhoid organism has been treated in this way, and the cell plasma obtained for the purpose of studying its toxic and immunizing properties. It would hardly have been anticipated that liquid air should find such immediate application in biological research. A research by Professor Macfadyen, just concluded, has shown that many varieties of micro-organisms can be exposed to the temperature of liquid air for a period of six months without any appreciable loss of vitality, although at such a temperature the ordinary chemical processes of the cell must cease. At such a temperature the cells cannot be said to be either alive or dead, in the ordinary acceptation of these words. It is a new and hitherto unobtained condition of living matter—a third state. A final instance of the application of the above methods may be given. Certain species of bacteria during the course of their vital processes are capable of emitting light. If, however, the cells be broken up at the temperature of liquid air, and the crushed contents brought to the ordinary temperature, the luminosity function is found to have disappeared. This points to the luminosity not being due to the action of a ferment—a "Luciferase"—but as being essentially bound up with the vital processes of the cells, and dependent for its production on the intact organization of the cell. These attempts to study by frigorific methods the physiology of the cell have already yielded valuable and encouraging results, and it is to be hoped that this line of investigation will continue to be vigorously prosecuted at the Jenner Institute.

And now, to conclude my address, I may remind you that I commenced by referring to the plaint of Elizabethan science, that cold was not a natural available product. In the course of a long struggle with nature, man, by the application of intelligent and steady industry, has acquired a control over this agency which enables him to produce it at will, and with almost any degree of intensity short of a limit defined by the very nature of things. But the success in working what appears at first sight to be a quarry of research that would soon suffer exhaustion has only brought him to the threshold of new labyrinths, the entanglements of which frustrate, with a seemingly invulnerable complexity, the hopes of further progress. In a legitimate sense, all genuine scientific workers feel that they are "the inheritors of unfilled renown." The battlefields of science are the centers of a perpetual warfare, in which there is no hope of final victory, although partial conquest is ever triumphantly encouraging the continuance of the disciplined and strenuous attack on the seemingly impregnable fortress of nature.

To serve in the scientific army, to have shown some initiative and to be rewarded by the consciousness that in the eyes of his comrades he bears the accredited accolade of successful endeavor is enough to satisfy the legitimate ambition of every earnest student of nature.

ELECTRIC PROCESS OF STEEL MANUFACTURE.

The electrometallurgy of iron and steel is at present exciting great interest. Mr. Marcus Ruthenberg's very interesting paper, read at the Niagara Falls meeting (this journal, page 84), elicited a long and animated discussion (this journal, page 58). Some information on results obtained in actual practice in Sweden and Italy were given in Mr. Carl Hering's synopsis (this journal, pages 70 and 71).

With regard to the plant in Gysinge, Sweden, a consular report of Mr. Robert S. S. Bergh, of Gothenburg, contains the following translation from a recent issue of the *Trading and Shipping Journal* of that city:

"At the meeting of the Iron Manufacturers' Association (Brukssocieteten) at Jernkontoret, Engineer F. A. Kjellin and Mr. Benedicks gave some very interesting information about the production of electro-steel at Gysinge.

"The problem of smelting steel by electricity has for a long time attracted the attention of inventors, and experiments have been made here. By the advice of Engineer Kjellin, Mr. Benedicks decided in 1899 to build at Gysinge an electric steel furnace 'without electrodes.'

"In the latter part of February, 1900, the first furnace was finished and ready for trial, and, after a few experiments, the first ingot was produced. The steel was found to be of excellent quality. The problem was thus solved technically, but not economically, for, with the dynamo of 78 kilowatts used, not more than 270 kilograms (575 pounds) of steel were obtained in twenty-four hours, and in the furnace there was not room for more than 80 kilograms (176 pounds). A larger furnace was seen to be necessary, and this was completed in November, 1900, and proved to be a great improvement. In the second furnace, which held 180 kilograms (397 pounds), from 600 to 700 kilograms (1,322 to 1,543 pounds) of steel were produced in twenty-four hours. The Gysinge sulphite factory burned down on August 11, 1901, and it was decided to build steel works in its place and to use the water power available there. For the steel furnace there was utilized a turbine of 300 horsepower, with direct-coupled generator. The new furnace is to hold 1,800 kilograms (3,970 pounds), and the production is estimated to be at least 1,500 tons a year if charged with cold raw material.

"Engineer Kjellin said that the steel produced is of superior quality and characterized by strength, density, uniformity, toughness and the ease with which it can be worked in cold, unhardened condition, even when containing a very high percentage of carbon. Compared with other steel, it also has less tendency to crack or warp when hardened.

"The reason why this steel in certain qualities differs from other steel, especially in its softness when unhardened, is considered to be its freedom from gases. The manufacture of special steel, with nickel, chrome, manganese or wolfram, will, of course, not meet with any difficulties. The chrome steel and wolfrom steel produced at Gysinge have proved to be excellent for lathe tool. When used for permanent magnets, the Gysinge wolfram steel has been found to give stronger magnets than any other wolfram steel, and has not warped in the hardening.

"From estimates made, it has been ascertained that the furnace used at Gysinge, which is simple in construction and easily managed, has prospects of competing, as to cost of operation, with the furnaces heretofore used for fusion of steel, especially as it yields steel of a better quality.

"For this country (Sweden), with its good ores and large supply of water power, the electric method of smelting steel ought to be of great importance, and abroad, where blast-furnace gas is becoming a cheap source of power, it ought to come into extensive use.

"After the lecture Engineer Wahlberg made some statements concerning tests of steel ingots from Gysinge, which had been found to be uniform and homogenous. Microscopic examinations had indicated that there was no difference between the electro-steel and crucible steel, which was so much more remarkable, as the electro-steel in other respects had different qualities."

REDISCOVERY OF A PROCESS FOR RENDERING PHOSPHORIC ACID AVAILABLE. *

BY PROF. CHARLES BASKERVILLE.

In endeavoring to secure a mechanical method for concentrating phosphatic pebble, found in the coastal plain region of North Carolina (Castle Haynes Mines), the concentric structure of many of the nodules was redetermined (Penrose, U. S. Geological Survey, Bulletin 46, 77). A number of analyses of carefully-selected pebbles were made, and in no case, except with the fossil teeth, which occur in the deposit to a greater or less extent, could samples be had which contained less than 15 to 20 per cent. each of silica and limestone.

The chemical methods for increasing the content of phosphate were unsuccessful from an economic point of view. Jigged material could be had, which contained from 35 to 44 per cent. of tri-calcium phosphate; so methods of fusing with substances like the alkaline, sulphates, sulphides, nitrates, and finally carbonates, were tried. The last was thoroughly successful, the nitrates giving the largest percentage of citrate soluble phosphoric acid, but the expensive nitrogen was driven off. Knoop (Bied. Centr.—B, 28,576) heated phosphates, bones, etc., with the alkaline silicates, and obtained a 99 per cent. yield of "available phosphoric acid." (U. S. patent, 601,089 (1898).

G. A. Liebig secured the American rights for a process the same as the author's, having preceded him by a few months. The process is of value in those countries where chamber acid is expensive (Sweden) and large deposits similar to the North Carolina carbonaceous and siliceous phosphates are found, as recently noted in Japan (*Science*, x, 900).

CURRENT NOTES.

THE Nobel prize for physics has been awarded to Professors Lorenz and Zeeman, the two distinguished Dutch physicists, who have taken active part in the development of the modern theory of electrons. In the subject of chemistry, the Nobel prize was awarded to Dr. Emil Fischer, who, as successor of A. W. von Hoffman, now occupies the chair of organic chemistry at the University of Berlin. Dr. J. H. van't Hoff, who occupies the chair of physical chemistry at the same university, received the Nobel prize last year. The amount of each prize is $41,600.

AT the annual convention of the American Roentgen Ray Society, recently held in Chicago, Prof. W. E. Goldsborough, chief of the department of electricity of the Saint Louis Exposition, made an address in which he outlined the plans of his department to bring together a thoroughly representative and advanced exhibit of Roentgen ray and electro-therapeutic apparatus. The convention passed a resolution extending assurances of its cordial support. Prof. W. E. Goldsborough also addressed the Interstate Independent Telephone Association at the recent convention in Chicago ,and a resolution was passed commending the Saint Louis World's Fair to the support of the independent manufacturers of telephone appliances and supplies.

THE president of the Exposition Co. of the Saint Louis Exposition has just announced the organization of world's congresses, to be held in Saint Louis during 1904. Howard J. Rogers, chief of the department of education, is to be the director of congresses. The Advisory Board, to work in conjunction with him, is as follows: Chairman, Nicholas Murray Butler, president of Columbia University, New York City;

* Abstract of a paper read before the Society of Chemical Industry.

William R. Harper, president of the University of Chicago; R. H. Jesse, president of the University of Missouri; Henry S. Pritchett, president of the Massachusetts Institute of Technology, and Herbert B. Putnam, librarian of Congress. The duties of this Advisory Board will be more exacting than usually falls to the lot of advisory bodies. Upon their recommendations will be determined the number and extent of congresses, the emphasis to be placed on special features, the prominent men invited to participate, the character of the programme and the methods for successfully carrying out the enterprise. No effort will be spared to give the series of congresses at this exposition unity and connected purpose, and make their published proceedings a valuable contribution to the world's literature. A series of congresses has been an accompaniment of all recent international expositions, but they have always been disconnected and rather incident to the exposition than related to it and supplementary to the exhibits. The work of the director and Advisory Board will be wholly given to constructing a co-ordinate department of the exposition, which shall have an established scientific value and attract the attention of the practical scholars and experts of the world to Saint Louis.

The Lousiana Purchase Exposition, in St. Louis, 1904, will have light effects that have not been exploited even in spectacular theatres. Chief Henry Rustin, of the electrical and mechanical department, is now conducting experiments to this end. The Nernst lamp is among those that are being tried. Other experiments are being made with the Cooper-Hewitt mercury vapor lamp, made by the Sawyer-Man Co., of New York. With this an initial pressure of between 50,000 and 75,000 volts is needed to start the light; then a pressure of only 120 volts suffices to maintain its luminosity. It is a livid phosphorescence, which imparts a ghostly pallor to objects surrounding, daylight colors being completely metamorphosed. Experiments are being made with other vapors than that of mercury, and with lamps of other patterns. It is desired to use in the cascades some phosphorescent light which will not only be luminous itself, but impart luminosity to the water it permeates. It is thought that the required agent has been found in the Geisler tube adaptation, with which experiments are now being made. These long tubes can easily be installed in the lips of the cascade ledges, and the light coming through the falling, turbulent water is expected to produce entirely unprecedented spectacular effects.

Dr. J. A. Holmes, chief of the mines and metallurgy department of the St. Louis Exposition, recently returned to St. Louis, after having been away about a month. He reports that the people of the Atlantic States now take a great deal more interest in the World's Fair than they did when he was in the East several months ago. Many of the manufacturers, who at that time were not disposed to exhibit at the fair, now announce that they desire to exhibit, and some of them have applied for space. At Pittsburg he arranged for a number of iron, steel, coal and coke exhibits, and at Philadelphia for several aluminum and iron exhibits. At New York he secured promises of exhibits illustrating different metallurgical processes in copper, lead and zinc; also exhibits in mining machinery. In Washington, D. C., he conferred with some of the Government officials in regard to exhibits illustrating ore deposits and the extent and distribution of mineral deposits in the United States. In Vermont he arranged for exhibits of slate, granite and marble.

The twenty-fifth anniversary of the Engineers' Club of Philadelphia was recently celebrated by a banquet. The guests included representatives from the national engineering societies, a large number of engineering clubs, as well as the Union League and Art Clubs of Philadelphia and the University of Pennsylvania. Among the distinguished guests were Admiral Melville and the venerable John Fritz.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

By Carl Hering.

INDUSTRIAL ELECTROCHEMISTRY.

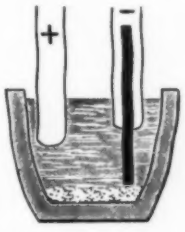
Bleaching.—The subject of bleaching powders and liquids is a matter which at present is becoming somewhat important, owing to the overproduction of bleaching powder as a by-product in the electrolytic alkali industry. During the past month several articles of interest in this direction have been published, one of which is on what seems to be a very simple method of producing hydrochlorite of soda for use in place of bleaching powder. The liquid must be made where it is used, but has a number of advantages which still further affect the bleaching-powder industry. The description of this cell of Walker will be found in *Eng. and Min. Jour.*, November 22d. He describes a cell devised by Atkins, of London, which consists of a semi-cylindrical wooden vat, with a horizontal axis, 10 feet long and 2 feet wide. The inside is lined with sheet lead, on which are placed carbon bricks about 2 inches thick, whose inner surfaces form a semi-cylinder concentric with the lead and wood, and act as anode; these carbon bricks are cemented together and to the lead by a water-proof carbon cement. A wooden cylinder covered with lead revolves as the cathode in the vat, within an inch of the surface of the carbons, and the solution of salt fills up the space between. The total area of the anode surface is about 20 square feet. The current used varies from 1,000 to 1,500 ampères at from 3 to 4 volts, and the amount of 10 per cent. solution of salt acted on varies from 500 to 1,000 gallons per hour, according to the strength of the resulting solution of hypochlorite that is required. While hydrogen is given off at the revolving cathode, the solution consists finally of NaClO and some unaffected salt. Owing to the great surface of the electrodes, there is very little resistance, so that the electrolyte hardly becomes heated at all, and thus no other reactions occur and no chlorates are produced. Preferably, the apparatus is worked at the bleaching plant, where the solution is at once used in the bleaching vats, as it is not practicable to store and ship the hypochlorite. No other chemical is required in the bleaching vat, as the hypochlorite rapidly gives off its oxygen when it comes in contact with the pulp or textile fabric and passes back to common salt again. One of the great advantages over bleaching powder is that no insoluble precipitate is formed. For this reason, and because chlorine has been too strong for this purpose, it has been impossible to use bleaching powder in whitening high-class linen. At the present time all the best linens of Ireland are sun-bleached. A large Scotch linen company are now trying the use of hypochlorite. A brief reference is made to the fact that the addition of sulphuric acid to the hypochlorite solution releases chlorine and oxygen, and forms sulphate of soda. It is said to be probable that this would be a better source of chlorine for chlorination than bleaching powders, and at any mine where fuel, water and salt are obtainable such cells might be erected for the direct production and use of chlorine, both in treating gold ores and in leaching low-grade copper ores.

A description of another apparatus for producing bleaching liquids is given in the *Electrochem. Zeit.* for October, its chief advantages being cheapness of the product and simplicity. The apparatus may be compared with a staircase, each step representing a self-contained electrolysis. The salt solution flows down these stairs from step to step, while on each step the electric current flows through it from one side to the other. The plates of every step contain 22 slots each, in which there are imbedded "peculiarly-formed bodies of platinum-iridium." The action of the new apparatus is said to be based primarily upon the fact that the salt solution is divided into thin liquid threads, and thus is subjected to the action of the current. Moreover, "the platinum-iridium bodies are so formed that the electrically-polarized surfaces are not of equal size, as in all other electrolyses, but the electrode polarized by chlorine has a surface several times as large as the electrode polarized by hydrogen."

The financial state of affairs concerning the bleaching-powder industry in England is discussed in an editorial note in the London *Elec.*, November 14th, which was prompted by the failure of the convention held by the English and foreign producers of heavy chemicals, which may be fraught with serious consequences for those of the new electrochemical works which depend upon bleaching powder for their profits. During the past four years bleaching powder has been maintained at an average price of $30 per ton by somewhate artificial means, and the electrolytic alkali works in this and other countries have benefited by the business arrangement existing between the English United Alkali Co., as representing the old Le Blanc process, and the Chemische Fabrik "Elektron," which is the German firm controlling nine-tenths of the electrolytic production on the continent. Under this arrangement the latter firm were allowed to dispose of 6,000 tons of bleaching powder per year in the United Kingdom, and the immediate cause of the rupture is said to have been a request that this quantity should be increased to 8,000 tons. Whether this explanation be correct or not, the fact remains that there was a failure of the agreement between the rival producers, and contracts have been signed for the delivery of large quantities of bleaching powder in 1903 at the low price of $20 per ton, delivered at the consumers' works. Should the value of bleaching powder fall to $17.50 a ton, as some believe it may, the margin for profit in this product would be practically wiped out, and many of the electrolytic alkali works would find themselves in an unenviable financial position. The one consolation is that the older Le Blanc will also be severely affected by the fall of prices, and their owners will doubtless be prepared, after a short period of open competition, to meet their rivals half-way in any proposals for the further regulation of prices.

Alkali Industry.—That prolific writer on electrochemical industries, J. B. C. Kershaw, begins another article in London *Elec.*, November 14th, in which he discusses the present condition of the alkali industries, beginning with that in the United Kingdom. This also bears on the subject of the bleaching industry, and on the overproduction of bleaching powder in Germany. The capacity of the Middlewich works of the Electrolytic Alkali Co. will be increased to 250 cells, and it is estimated that the output will then amount to 12,800 tons of bleaching powder and 18,000 tons of soda crystals per year. The Weston Point works of the Castner-Kellner Co. have paid a dividend of 6 per cent. for the last year. Both at Middlewich and at Weston Point the concentration of the alkaline liquors running from the electrolytic cells is carried out by means of multiple-effect evaporators. The total power available at Middlewich and Weston Point for the production of alkalies and chlorine products is now between 5,000 and 6,000 horse-power, and when the additions to the Middlewich plant are completed over 7,000 horse-power will be devoted to the electrolytic decomposition of salt in that country. Should the whole of the chlorine liberated from the salt be converted into bleaching powder, the aggregate production of this chemical by the two electrolytic plants will be about 25,000 tons per year. In Germany, the group of electrolytic alkali works under the control of the Griesheim Co. "Elektron," situated at Bitterfeld, Griesheim and Rheinfelden, appear to be working satisfactorily. The new Aussig "bell" process is being operated at one of the Bitterfeld works, and it is probable that in course of time it will be generally adopted by all the works under the control of the Griesheim firm. At the Bitterfeld plant the annual output of caustic potash and bleaching powder is 7,200 and 12,250 tons respectively, and, in addition, considerable amounts of sodium and magnesium are produced. The output of the Rheinfelden plant is 5,800 tons of caustic potash and 10,000 tons of bleaching powder per year. The maximum output of the group of works at Griesheim, Bitterfeld and Rheinfelden is 25,000 tons of caustic potash and 40,000 tons of bleaching powder per year; and the electrolytic works of the Solvay Co., at Osternienberg, add about 5,000 tons to the latter total. The German home demand for bleaching powder is, therefore, more than covered by the output of the electrolytic plants, and the development of the export trade in bleaching powder is essential for the maintenance of the German electrolytic alkali industry. Already in 1900 the total exports amounted to 25,953 tons, while only 398 tons were imported.

Furnaces.—In the "Synopsis" of last month the method of Borchers and Stockem, for the production of metallic calcium, was described. This article has apparently brought forth a description of another method of ARNDT, by which he claims that the same result may be obtained with a more simple apparatus, which he describes in *Zeit. f. Electrochemie*, November 13th. He uses an iron crucible, which is coated inside with the material of fire-brick, mixed with water to a creamy consistence; the bottom is also covered with a layer of fluor spar, and the whole is dried in a warm place for twenty-four hours. A carbon rod is used as anode, and a thick iron wire as cathode, which is covered with a porcelain tube to about 4 cm. from its lower end, as shown in the adjoining diagram. To cool the crucible, it was placed on a large iron block. To fuse the calcium chloride, which, freed from its water, was gradually introduced into the crucible, an arc was used between the carbon anode and a carbon rod (not shown in the figure) held in the hand, and also connected to the negative pole, until the current passed through the bath; the current was then held at 20 to 25 ampères. After having beaten the contents of the crucible to pieces, he found metallic calcium in larger well-fused pieces, which could be easily hammered and filed. At fresh surfaces the metal is nearly white, but soon gets a yellow color. The analysis of a piece thus produced showed 99 per cent. of calcium and 1 per cent. of silicum, no iron or aluminum being present.



CALCIUM FURNACE.

DANNEEL continues, in the *Zeit. f. Electrochemie*, September 25th, the description of other processes which have been worked out in the metallurgical laboratory of the Institute of Technology of Aix-la-Chapelle. Some notes are given on preliminary experiments of Borchers, which are to be continued on a large scale, for the production of chromium, free from carbon, in the electric furnace, chromic oxide being placed over a mixture of aluminium oxide with the amount of carbon required for the reduction. Experiments of Stockem are also described. He endeavored to produce cerium by electrolysis, the object being to utilize the waste materials of the gas incandescent lamp manufacture. Cerium is best obtained from the fused chlorides, free from water; less favorable results are obtained with the reduction of the oxide. By the Goldschmidt reduction process, cerium could not be obtained. Some experiments by Borchers and Dorsemagen are noticed on the preparation of red lead, or minium, from lead peroxide and lead oxide. Some

notes are also given on nickel refining, the modern "tops and bottoms" process being represented diagrammatically, and some modifications suggested by Borchers and Guenther being noticed. A detailed article by Guenther on this subject is promised in the near future.

Testing of Alloys.—Electrochemical methods seem to be gradually replacing former methods for doing various things. Sirks recently described such a method for testing alloys for industrial purposes, which description will be found in the *Proc. Roy. Akad., Amsterdam*, September 27th, a brief extract of which is given in the London *Elec.*, November 14th. Formerly the specimens were polished and exposed to a tempering flame. The different oxidizing action on the various constituents brings out the crystalline structure of the alloy and gives valuable hints concerning its mechanical properties. Instead of tempering, the metals may also be etched in acids, but this method has various disadvantages, owing to gas bubbles and the like. These difficulties have been removed in the electrolytic method of the author. The specimen is made the anode in an electrolytic cell, with copper as a cathode. Direct current at 4 volts is used; the electrolyte is water with six drops of dilute sulphuric acid per 100 cc. In this way the formation of basic metallic deposits is avoided. Since the etchings are much more pronounced in this method than in the simple acid etching, it is not necessary to polish the specimens; smooth filing suffices. It is possible to etch out individual crystals of the alloy, showing a definite and invariable proportion of the constituents. These crystals are the product of a chemical reaction between the constituents which has a profound influence upon the mechanical properties of the alloy.

Recovery of Tin from Tin-Plate Scrap.—The *Chem. Industry*, 1902, page 625, publishes a note on a Swedish patent of Bergman, which is abstracted in the *Eng. and Min. Jour.*, November 15th. He introduces the scrap into an iron vessel filled with a solution of caustic alkali, together with a depolarizer, but no copper oxide. Electrical action sets in; the scrap is stripped, and the tin goes into solution as a stannate of the alkali. When a saturated solution is obtained, the tin is precipitated as oxyhydrate by means of a current of carbon dioxide. The precipitate is filtered off, dissolved in acid and the tin is separated out electrically.

Electrometallurgy.—A series of articles by Beadle is published in the London *Elec. Rev.*, September 26th, October 10th and 24th and November 14th, on electrometallurgical problems, especially those discussing the methods which have been proposed for producing metals from the ores. The first three articles deal with copper, lead and zinc, but do not seem to give anything new. The last one is on the production of gold and silver.

THEORETICAL AND EXPERIMENTAL.

Artificial Diamonds.—The experimental researches of Moissan, in which he produced true diamonds in the electric furnace, seem to have interested others in similar directions, and it is not at all unlikely that at some time in the no distant future diamonds may be produced artificially so much cheaper than the natural diamonds that much of the interest now lying in their possession may be lost. Ludwig seems to have had greater success than Moissan, at least in producing diamonds of larger size, as he obtained them as large as a pea. His experiments are described in the *Chem. Zeit.*, vol. 25, p. 979, an abstract of which is given in the *Am. Jour. Sc.* for December. His results may be of special interest, as it is his intention to develop the processes so as to manufacture diamonds on a commercial scale. It was shown by Pepys, in 1815, that an iron wire heated to redness in contact with diamond was converted into steel. The present author claims that, under great pressure, in an atmosphere of hydrogen this reaction is reversed, and also that carbon fused in the electric arc in the absence of iron, under the same conditions of pressure, is likewise converted into diamonds. In carrying out the experiments, pressures as high as 3,100 atmospheres were used. A spiral of iron wire was imbedded in powdered retort carbon and heated by an electric current in a highly-compressed atmosphere of hydrogen. In a few moments the resistance, which was slight at first, on account of the conductivity of the carbon, rose to that of the iron spiral. This indicated that the carbon in contact with the spiral had become non-conducting, and careful examination showed that on some of the pieces of carbon were brilliant, minute crystals, possessing the hardness, specific gravity and refraction of the diamond. The greater part of the carbon contained in the iron spiral had also been connected into diamond. The crystals had the characteristic irregular surface shown by the diamonds produced by Moissan by the sudden cooling of molten iron. To produce diamonds without the use of iron, it was found necessary to use much higher temperatures, and actually fuse the carbon under very high pressure. Thus fused, it was shown to be a non-conductor, and hence was considered to be the molten diamond. Under the pressure employed, this fusion took place very easily in the electric arc, and there were thus obtained spherical masses of the size of peas, having great hardness and crystalline structure.

Electrolysis of Fused Caustic Potash.—In the *Zeit. f. Electrochem.*, October 23d, Le Blanc and Brode give an account of their experiments, which are in the form of a continuation of their investigations of the electrolysis of fused caustic soda and potash, recently noticed in this Synopsis. In fused caustic potash the ions are K and OH, and the development of hydrogen at the cathode results from the presence of water dissolved in the fused bath. The values of the decomposition voltage are nearly the same as for caustic soda. From their experiments they conclude with positiveness that it is impossible by Castner's process, in the presence of air, to produce metallic potassium (as distinguished from sodium) from pure fused caustic potash on an industrial scale. They think that Castner probably worked only with fused caustic soda. The impossibility of producing metallic potassium by Castner's process is thought to be due to the fact that metallic potassium at that temperature oxidizes very easily.

Lead as Anode in Sodium Hydroxide Solutions.—Experimental investigations were recently made by Elbs and Forssell of the behavior of lead as anode in sodium hydroxide solutions and of the electrolysis of sodium hydroxide solutions containing lead oxides. The principal results are as follows: A lead anode dissolves in sodium hydroxide under different conditions, but always as bivalent lead. In the electrolysis of sodium hydroxide solutions, containing lead oxides with an inert anode, the primary electrolytic action at the anode is the discharge of lead oxide and oxygen, while lead peroxide is secondarily formed; hence the amount of peroxide formed per coulomb increases considerably with increasing temperature. Moreover, the speed of formation of the lead peroxide depends greatly on the material of the anode; the discharged anions have mostly the formula $HPbO_2$ (monovalent). Lead peroxide is formed upon a platinum anode at 20° C. at a voltage which is lower by 0.23 volt than that required for the formation of lead oxide and oxygen. Lead peroxide has, like platinum and some other metals, the property to occlude oxygen, and at a certain voltage the pressure of the occluded oxygen is probably the same as on platinum. The formation of lead peroxide and the re-formation of ions of bivalent lead from it in alkaline solution is not a reversible process. The experiments are described in the *Zeit. f. Elektrochemie*, October 2d.

Electrolysis of Silver Nitrate.—A note is published in the London *Elec. Eng.*, November 7th, stating that while it is generally said that silver nitrate becomes acid during electrolysis, yet Roger and Watson found that the acidity diminished. The apparent contradiction has been explained recently by Leduc as being due to a difference of the conditions. With platinum electrodes in a sufficiently-concentrated solution, a brown solid, containing a higher oxide of silver, is formed with the

simultaneous formation of nitric acid, which, however, when a sufficient concentration is reached, reacts on the compound with the formation of oxygen. Similar results are obtained with soluble anodes and a sufficient current density, and the acidity of the bath therefore leads to a limiting value. He finds that a corrosion or solution of the cathode deposit does not take place, and the experiments also indicate that in a silver nitrate voltameter the polarization e. m. f. is about 0.03 volt.

Amalgam Potentials.—REUTER gives an account in the *Zeit. f. Elektrochemie,* October 16th, of an experimental investigation of the electromotive behavior of potassium amalgams. Haber and Sark previously investigated sodium amalgams, and the present author found that his results correspond with theirs. His principal results are as follows: Potassium amalgams containing very low to high per cents. of potassium were prepared, and their potentials were measured in a solution of 1.56 per cent. LiCl in methyl alcohol. The other electrode was Ostwald's well-known mercury standard electrode. The measurements were made at — 80° C. The results are plotted in the form of a curve, which shows a characteristic and large break in continuity at the point corresponding to the alloy $Hg_{11}K$. The potentials have about the position in the curve which they should have according to Berthelot's rule, the heat of formation measuring the change of free energy. The potential of pure potassium and pure sodium is lowered considerably by slight additions of mercury.

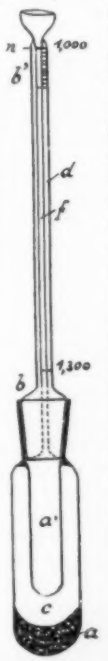
Reduction by Calcium Carbide.—As is well known, this material may be used for the reduction of metallic oxides and salts, the action being similar to that of aluminum, but much more powerful. There seems to be some doubt, however, about the formula representing the process, and this is of practical importance, as it shows the quantities required, which may decide whether or not a process becomes practicable. Two papers have recently been published, one by NEUMANN, in the *Zeit. f. Elektrochem.,* October 2d, and another by VON KNEGELGEN, in the same journal, October 9th. Both have investigated its action, but have reached different conclusions concerning the formula. The formula found by the latter requires considerably less carbide for the process, and it therefore appears less hopeless for practical application. The principal difference between the views of the two authors is that Neumann assumes that primarily carbon monoxide is formed, while von Knegelgen assumes the primary formation of carbon dioxide. Neumann has made some gas analytic measurements, and claims that they prove the correctness of this view; von Knegelgen denies that this is proved by those measurements, and promises the publication of a more detailed study of the problem.

Oxidation Processes.—BODLAENDER has written a long article in the form of a contribution to the theory of some technical reduction and oxidation processes. It seems to contain very valuable figures, but cannot be abstracted. It is published in the *Zeit. f. Elektrochemie,* October 30th. At the end of the article the author gives the most important interpolation formulas for the free formation energies, relating to the oxidation of carbon to carbon dioxide, the oxidation of carbon to carbon monoxide, the oxidation of carbon monoxide to dioxide, the formation of carbon monoxide from carbon and carbon dioxide, the combination of hydrogen and oxygen, the oxidation of zinc, the oxidation of iron and the formation of hydrochloric acid from hydrogen and chlorine.

Maxwell's Theory and Electrolysis.—In the *Electrochem. Zeit.* for September PLATNER concludes his mathematical article on Maxwell's theory of electricity and its importance in the theory of electrolysis. The electrolyte is compared by him with Maxwell's dielectric medium. The electric force produces in this medium a condition similar to elastic tension (dielectric displacement). There are pressures produced in the medium which result in mechanical motion, there being a tension along the lines of force and a pressure perpendicular to the lines of force. He adds the supposition that the different materials of the electrolyte react in a different manner against these forces, and thus gets what he believes to be a basis which is quite sufficient for the explanation of electrolytic phenomena without the use of any "fantastic hypothesis."

Chemical Effects of Canal Rays.—G. C. SCHMIDT recently published an account of an experimental investigation in which he endeavored to find whether positive ions in gases exert an oxidizing action. This might be expected, as the negative electrons in cathode rays are known to have a strong reducing effect, which has been explained by the assumption that the negative electron satisfies a positive valency of the metallic atom, so that this requires a lower valency than before. By an argument based on analogy, it might be expected that canal rays, which are assumed to consist of positive ions associated in some way with neutral atoms, would exert an oxidizing action. The author did not, however, find any well-defined oxidizing action. There is powerful decomposition, but it depends upon the nature of the gas and the compound whether the decomposition results in an oxidation or in a reduction. Solid solutions which show luminescence under cathode rays show the same under canal rays, but it decreases rapidly, owing to the decomposition, which is indicated "by the spectrum of the glow becoming whitish." If the gas in the tube is oxygen, and an oxidizable body is in it, the latter is oxidized. If, on the other hand, the gas is hydrogen, the latter reduces any compound capable of reduction. The most typical reaction for canal rays is the decomposition of sodium compounds; it takes place even when only traces of sodium are present, and is revealed by the D line. The article may be found in the *Ann. d. Phys.,* November 11th, and is abstracted in London *Elec.,* November 14th.

Determining the Specific Gravity of Liquids.—The *Centralblatt f. Accum.* of November 1st publishes an illustrated description of a new "araeo-pyknometer," devised by RAIKOW, which enables one to easily determine the specific gravity of the same small quantity of a liquid at different temperatures in succession. As will be seen in the adjoining illustration, the instrument consists of two parts, the lower one *a a'* and the upper one *b b'*. The lower one is divided into three portions: the lowest *a* is filled with mercury, the second *c* is empty and the third *a'* contains the liquid the density of which is to be determined. The upper end of the latter forms a neck, into which the upper part of the apparatus is set in like the stopper of the neck of a bottle. This upper part consists of two tubes *d* and *f*, the latter being thin, of a diameter of about 1 mm., and placed in the central part of the tube *d*. The two tubes are fused together at the two ends. The instrument is used as follows: The upper part is taken out, and the portion *a'* is filled with the liquid to be tested so that it reaches somewhat into the neck; then the upper part of the instrument is put into the neck, and the whole instrument is placed into water of the desired temperature. The liquid is then drawn out of the upper funnel until it reaches the mark *n* on the scale, with which the tube *d* is provided. Then the floating capacity of the araeo-pyknometer is determined in distilled water in the ordinary way, the specific gravity of the liquid tested being read from the scale. When the specific gravity of a liquid at a certain temperature has been determined, and one wants to find it at another higher temperature, it is only necessary to raise to the desired amount the temperature of the water in which the instrument floats and to again adjust the liquid level in tube *f* exactly to mark the *n*. In case one wants to determine the specific gravity at a lower temperature, one first adds one or



ARAEO-PYKNOMETER.

two drops of the liquid into the funnel and then cools the water to the desired lower temperature, all other operations being as before.

Organic Chemistry.—Several papers have recently been published on the application of electrochemical methods to special subjects in organic chemistry: one by Loeb, in *Zeit. f. Elektrochemie*, October 2d; another by Elbs and Brand, Elbs and Wohlfahrt and Klappert, in *Zeit. f. Elektrochemie*, October 9th, and a third by Escherich and Moest in *Zeit. f. Elektrochemie*, November 6th.

PRIMARY AND SECONDARY BATTERIES.

Batteries for Electric Launches.—The scant literature on batteries during the past month contains an illustrated description by Dreihardt of the electric launches exhibited at the International Self-propelled Boat Exposition, at Wannsee, Berlin, 1902. The number of cells in these boats is generally 40 or 80, in order to be able to charge the battery directly from a 110 or 220-volt station. Occasionally boats with 200 cells have been made for charging from 550-volt stations. The charging is nearly always done with constant voltage and variable current, which enables one to complete the charge more quickly and with less attendance. The largest of the three boats exhibited has a battery of 80 cells, each having 15 positive Planté and 16 negative Faure plates. The capacity is 450 ampère hours for a six-hour discharge. The total weight of the battery is 7,000 kg. The description is given in the *Centralblatt f. Accum.*, November 1st and 15th.

Explosion in a Storage-Battery Plant.—There were two accidents recently, of a somewhat serious nature, in some storage-battery plants in Germany, which were due to the explosions of the hydrogen and oxygen produced electrolytically in the batteries and used for soldering purposes, a practice which seems to be becoming common in German accumulator works. A description of these accidents is published by Schoop in the *Elec. Zeit.*, November 6th. He recommends taking care to exclude all organic substances from contact with the oxygen, and to use nothing but water for lubricating the valves; also to take care to keep the receptacles for the oxygen and hydrogen separate from each other, so that no mixture of the gases, by carelessness or otherwise, may take place.

Storage Batteries at the Dusseldorf Exposition.—London *Eng'ing*, September 17th, continues the long serial on the chemical and metallurgical industries exhibited at this exhibition. It seems that the electrochemical exhibits were confined to storage batteries, and in the present portion those exhibited by various German firms are described.

GENERAL AND MISCELLANEOUS.

Water-Power Plants.—A number of large power plants, intended more particularly for electrochemical processes, were described during the past month. Among these there is an illustrated description in *L'Ind. Elec.*, October 10th, of the Clavaux plant of the Société d'Electrochemie. The 5,000 horse-power is available during eight months, while at low-water level the available hydraulic power decreases to 3,000 horse-power. The horizontal axle turbines have a capacity of 550 horse-power, the normal speed being 250 revolutions per minute. There are five 375 kw. direct-current generators direct-coupled to the turbine. A small 80 kw. generator furnishes the current for light and for various motors in the plant. Each of the 375 kw. direct-current generators is provided with two independent commutators, each giving 2,500 ampères and 75 volts. Only three generators are at work at present. The purely electrolytic processes are mainly for the production of sodium and peroxide of sodium by the Castner & Hulin method.

Several plants in the Alps are described in the *Elec. Age* for December, forming a third part of a series of articles. The French electrochemical and electrometallurgical industries have their principal centre of activity in the region of the Alps. This article first gives a list of 17 power houses, of together 74,000 horse-power, a large portion producing calcium carbide, besides chlorates, aluminum and sodium. Some notes are also given on the installation of the power houses at Giffre, at Chedde, at Chapareillan, at Pontcharra and on the Arve.

The Sault Ste. Marie power house is described in *Cassier's Mag.* for December, by von Schoen.

Fused Quartz.—The very great advantages of the use of quartz in place of glass, namely, its great strength, the fact that it can be heated to about 1,400° C. without changing its shape, and the fact that such vessels can be heated without cracking, make the subject of the production of articles in fused quartz a very attractive one, and one which it seems promises to be developed in the near future by means of the electric furnace. Quartz may be welded, blown and shaped just like fused glass, the only difference apparently being in the fact that a very high temperature is required for its fusion, and, unless well fused, difficulties arise in the production of bubbles in the mass. Heraeus, in Germany, has succeeded in making such apparatus by means of the oxyhydrogen flame; Shenstone has worked in Great Britain with the same flame; Hutton, of Manchester, England, has worked with the arc, as was described in his recent Electrochemical Society paper at Niagara Falls. According to the *Zeit. f. Elektrochem.*, November 13th, another German firm now make such articles commercially, although the price is still rather high and the production of small air bubbles in the mass cannot yet be entirely avoided.

Removing Hair by Electricity.—It seems that the electric method of removing hair so that it will not grow again has proved to be the surest, although it is at the same time the slowest, process. It is described in the *Arch. d'Elec. Med.* for October 15th, in an article by Guilloz, which is abstracted in London *Elec.*, November 14th. The cathode is in the form of a fine needle of platinum, gold or, best of all, steel. It is introduced into the skin alongside of the hair to the bottom of the bulb, and a current of 1 or 2 milliampères is passed for a time varying from twenty to fifty seconds. The action is said to be that of a galvano-cautery, but the account also says that hydrogen is disengaged around the end of the needle and appears as a white foam, and it may therefore be electrolytic. It appears that the destructive action will affect the roots of the hair, even though the needle may not be in actual contact.

Electrolysis and Physiology.—Berthelot, in *Comptes Rendus*, September 29th, gives an account of an investigation of certain voltaic cells whose behavior has an important bearing upon the physiological action of the animal cells composing the human body. He studied more especially the very small chemical transformation accomplished in a single animal cell during the impact of a single blood wave. An abstract is given in the London *Elec.*, October 31st.

Standardization of Methods of Chemical Analysis.—Blount, in a paper in London *Eng'ing*, November 7th, draws attention to the growing demand for standardization. While necessary for such quantities as weights, money, etc., the desirability of standardization is less incontestable for wire and sheet gauges, screw threads, etc., debatable for the dimensions of rails and rolled joists and doubtful for the testing of materials used in construction. Passing to the standardization of chemical analysis, he draws a distinction between the provision for standard samples of steel and the establishment of standard methods of analysis. The discordance of views held by chemists on standard methods is, to some degree, due to want of mutual understanding. The arbitrary methods in use for the examination of water, milk, oils, foods, manures, etc., should be standardized, but true analytical processes, such as the determination of all elements and most inorganic and many organic bodies, cannot be. Standard methods for the determination of a chemical entity cannot be imposed upon trained chemists. Yet he advocates conferences of specialists in dif-

ferent branches of analysis for the discussion of methods, though not for the promulgation of rules. The agitation for standard methods has arisen in a great measure from the occurrence of discrepancies in analysis, due to bad sampling and unskilled work, which cannot be remedied by standardization. With good sampling and skillful work, uniform results will be obtained, irrespective of uniformity of methods. The chemist, he thinks, should be better trained and better paid.

Dusseldorf Exposition.—DANNEEL continues his illustrated serial on the electrochemical exhibits in the *Zeit. f. Elektrochem.*, October 16th and 23d. Several instruments of Hartmann & Braun and electric laboratory furnaces of Heraeus are described and illustrated, and some data are given on power gas installations.

German Electrochemical Patents.—Some statistical work of the German Patent Office during the past ten years is given in the *Electrochem. Zeit.* for October.

Owens College Laboratory.—The electrochemical laboratory at this college in Manchester, under the direction of R. S. Hutton, is described by WALKER in the *Eng. and Min. Jour.*, November 15th. This is the first laboratory in England for study and research of electrochemistry and electrometallurgy.

Electrochemical Engineering.—Under the title of "Elektrochemisch Technik," the *Centralblatt f. Accum.* now publishes a supplement in the form of the repertorium of new articles, papers, patents, etc., on electrochemistry, arranged in alphabetical order.

Book Reviews.

ELECTROCHEMICAL ANALYSIS. By Prof. Edgar F. Smith. Third edition, revised and enlarged. 204 pages, illustrated. Philadelphia: P. Blakiston's Son & Co., 1902. Price, $1.50.

There is probably more accurate and exact information on the general subject of the electrodeposition of metals inside the covers of a treatise on electrochemical analysis than in any other kind of publication. After wandering through the maze of poorly-arranged, uncritical and indefinite information on this subject, such as is found in most works on "electrometallurgy," it is wonderfully refreshing to find exact quantitative data, obtained under test conditions, with all the accuracy of description and operation required by the exigencies of quantitative chemical analysis. To any such wanderers, who may have come to feel perhaps that electrometallurgy is largely a rule-of-thumb trade, a perusal of such a book as this of Professor Smith's is heartily recommended as an anti-bilious corrective.

While not so pretentious as Classen's work on the same subject, the work, as a book of instruction, is probably more useful. The author describes many home-made devices and laboratory arrangements of his own in such familiar style as causes the difficulties of the subject to vanish, and puts the student at once at his ease; he is being instructed by a practical co-worker. The introductory chapters on the action of the electric current on salts, the definitions of electric current, sources of the current, resistances, measuring instruments, description of laboratory and historical sketch of the subject, are all interestingly written, but in some cases the striving for brevity and conciseness has been at the expense of completeness, and a few more pages on some of these heads would have avoided ambiguity and given the student a more just appreciation of the subject.

In the determination of the separate metals and separation of metals from each other, nearly every page contains the complete data and results of critical tests of the methods described, made by the author or his students. Diagrams of the arrangement of apparatus are supplemented by photographs of the apparatus in actual use, taken by Mr. Taggart, and references to the literature of the subject are abundantly given. In the reviewer's opinion, this part of the book (which is, after all, its essential part) is not equaled by any other publication on electrochemical analysis, and will be of great service to every electrochemist, be he purely scientific or practical.

The author speaks, on page 102, of using a current of "2 ampères *per minute*," a mistake which has been carried over from a former edition, and which ought to be corrected. The author's definitions of *volt* and *ampère* need defining more closely, as in their present state they suggest the predicament of the hero of the "Nonsense Book," whose utmost endeavors to find the difference between a *snark* and a *boojum* resulted only in the information that "a *snark* is a *boojum* and a *boojum* is a *snark*."

MONOGRAPHIEN UEBER ANGEWANDTE ELEKTROCHEMIE. Vol. II. Die Gewinnung des Aluminiums und dessen Bedeutung für Handel und Industrie. By Adolphe Minet. Translated into German by Dr. Emil Abel, Halle a. S.: Wilhelm Knapp. 129 pages, with 57 illustrations and 15 tables. Price, marks 7.

The present volume is the second one of the series of "Monographs on Applied Electrochemistry," edited by Victor Engelhardt, chief engineer of the Siemens & Halske Co., of Vienna. The author is Adolphe Minet, the inventor of the Minet process, who for a number of years has devoted his attention to the manufacture of aluminum. The book is divided into two parts, the first dealing with the production of the metal, the second with its physical properties, alloys and applications in the arts. In the first part the author takes up, in the order named, the chemical methods, with and without the use of sodium, the electro-thermic and the electrolytic methods. The most interesting part of the book for the electrochemical public is the one which is devoted to a description of Minet's own methods and experiments. These are described at length, and various interesting data are given. It is worthy of note that Minet still clings to the opinion about the reactions taking place in his process, which he expressed in his first patent, in 1887, namely, that aluminum fluoride is primarily decomposed by the current. While he devotes over 20 pages to his own process, he treats the Héroult process, which is a great deal more important than his own, on four pages, and the Hall process, which is at least as important as the Héroult process, is dismissed with about 30 lines and a reprint of half a dozen of schematic patent specification figures, either taken from Mr. Hall's patents or from Borchers' "Electrometallurgie." The description of the other processes, besides these three, is given in condensed form, following in the main the exhaustive treatise of Prof. J. W. Richards on "Aluminium" and Borchers' "Electrometallurgie," and the majority of illustrations given in the latter under the head of aluminum are reproduced. In marked contrast to both of these authors, however, Mr. Minet frequently omits to enumerate the specific references to his sources of information, and merely mentions the names of his authorities. There is also a great discrepancy between the figures of the production of aluminum in the various countries which he gives and those that are given at other places. For instance, he gives as the production in 1900: United States, 1,650 tons; Switzerland, 1,232 tons; France, 800 tons, and England, 500 tons. The production as given in the *Mineral Industry*, Vol. XI, 1902, for 1900 is as follows: United States, 3,243 tons; Switzerland, 2,500 tons; England, 500 tons, and France, 1,500 tons.

Considering the book as a whole, one cannot fail to feel that the expectations which the name of the author on the title page might have given rise to have not been fulfilled. As a textbook, it cannot compare with J. W. Richards' presentation of the subject in his well-known work on "Aluminium." Coming, however, as it does from a man who has had a great deal of experience in the manufacture of the metal, it cannot fail to be of interest to anybody who is familiar with the subject, and, despite its shortcomings, is well worth a perusal.

Elementary Chemistry. By F. W. Clarke, Chief Chemist of the United States Geological Survey, and L. M. Dennis, Professor of Inorganic and Analytical Chemistry in Cornell University. New York: American Book Co. 340 pages and 51 illustrations. Price, bound in cloth, $1.10.

In this small volume the distinguished authors present an elementary text-book of chemistry, intended to be used by two classes of readers: First, those to whom chemistry is only one item in a general education, and, secondly, those who intend to take a more advanced course in chemical training. For the first class the book is sufficiently full; for the second class it is intended to serve as a legitimate basis for subsequent higher study. As the authors remark in the preface, "the study of chemistry, apart from its scientific and detailed applications, is a training in the interpretation of evidence, and herein lies its chief merit as an instrument of education." This idea is constantly kept in mind throughout the book. A reasonable number of experiments are described, and each generalization is made to follow the evidence upon which it rests.

The subject is rendered attractive and interesting to the student by constant references to the application of chemical science to human affairs, its utility in modern life, the technical methods of manufacture and the various uses of the substances discussed; 266 pages of the book deal with inorganic chemistry, 58 pages with organic chemistry.

Electrolytic action is very briefly and somewhat vaguely discussed on pages 163 to 167, but more can hardly be expected in an elementary text-book of chemistry. Page 167 contains the statement: "Most bases and most acids contain hydroxyl, OH, and when they unite they do so with evolution of water." According to modern ideas, the characteristic feature of a base is that it contains OH ions, and the characteristic feature of an acid that it contains H ions; in the formation of a neutral salt from an acid and a base, the H ions of the former and the OH ions of the latter combine directly to water.

The methods of electroplating and electrotyping, also the electrorefining of metals and the electrolytic manufacture of aluminum are noticed.

On pages 10 and 11 the term "force" is used in a very indistinct way. The authors speak of the conservation of force, instead of energy. They say that "such things as heat, light, electricity, mechanical power, etc., are called forces." Later on force is used in its correct sense.

THE PRESENT POSITION OF THE STORAGE-BATTERY INDUSTRY IN GERMANY.*

In the manufacture of storage batteries by the big companies, a tendency has prevailed in recent years to disregard inventions which were enticing from a theoretical point of view, but seemed to be of questionable value for the practice, and the principal aim was to make a cell of a construction as simple as possible. The result has been that the cells made by different firms are so similar that the selling of storage batteries might be called, in the strict sense of the word, a trading in lead. The position of the buying agent has become the most important one.

The raw materials are lead, sulphuric acid and glass. No saving can be accomplished in the purchase of the glass, which represents only a small fraction of the total cost. Sulphuric acid is made in many plants as a by-product at so low a cost that the prices differ only slightly. Thus the most important point is to buy the lead cheaply.

About a year and a half ago the price of 100 kilograms (220 pounds) of pure soft lead (purity 99.98 per cent.) was marks 37 ($9.25). To-day the greater firms have made contracts by which they get the lead at a price of marks 21 to 25 ($5.25 to $6.25). The price of the lead has fallen step by step, and it is not impossible that it may even fall further. The American Lead Trust is not likely to change this condition. On the one hand, Australia's and Spain's inexhaustible lead mines are strong competitors, as lead commands cheap freight rates, owing to its use as ballast in steamers. On the other hand, German silver and other mines produce large quantities of relatively very good lead at low prices. Neither will the duty proposed in the new German tariff be of great influence. It may be that the prices will rise slightly. In the next few years the German storage-battery manufacturers may have nothing to fear from the competition of foreign industries, which are still in their infancy. Should the lead price rise again to its former value, the only result would be that the consumer has to pay more.

In the purchase of lead, cash payments are the rule. The electrical energy for forming the plates and the wages for the workingmen also require cash payments, and the firm which promptly pays gets the lowest prices. It is therefore evident that only those storage-battery manufacturers who possess large reserves of floating capital can manufacture with profit. Recently the general manager of a Southern German storage-battery plant of good reputation stated privately that, at the present low prices, the plant sells its batteries with loss.

The development of the German storage-battery industry in recent years has already resulted in failures of several smaller companies, and this development will continue, with a stubborn fight of the surviving firms to the finish, if the leading managers don't prefer to unite. The "Cartell" (syndicate), which had been formed last year, has found a sudden death, as it was founded on a wrong basis. As it is easier to induce three competitors to unite than fifteen or more, the time will be ripe for a syndicate when still more companies will have failed, and the few survivors, after having fought bitterly, will recognize that they are of equal standing. The result will be a trust, and, as long as its members don't disagree, no outsider will be able to succeed in establishing himself in the industry if he has not a capital of several millions.

Better conditions prevail in the sale of automobile storage batteries, but the demand is not great.

* Translated from the *Centralblatt für Accumulatoren-Elementen und Accumobilenkunde*, Oct. 15.

AMERICAN AUTOMOBILE BATTERIES.—I.

THE SPERRY BATTERY.

In the Sperry battery, which is manufactured by the National Battery Co., Buffalo, N. Y., the grid, as shown by Fig. 1, is made of thin, pure sheet lead, which is corrugated horizontally. In the bottom of the hollows, formed by the corrugations, numbers of small trapezoidal holes are punched. The punch also cuts diagonally across the trapezoid, and, instead of making a clean hole, fins are left which project on either side of the plate. The whole plate, when punched, resembles a corrugated grater, except that the fins are longer and triangular in shape. These projections are then spread wider apart, so that a pressure on the plate will cause them to bend down in a direction away from the holes from which the fins project.

The material which is to become active is spread in the form of a powder on both sides of the grid, filling up the corrugations and being in sufficient quantity to make a flat plate of usual thickness after press-welding. The whole is then subjected to pressure—about 1,000 pounds per square inch of surface—which forms it into a solid mass. The material is bound to the grid by being pressed together into a continuous mass, which is on both sides of the grid and is welded through the multitude of small holes, thereby riveting itself in the grid. Additional hold is furnished by the fins, which bend down and are clinched over the active material, and thus retain the material at the surface.

The retention by the fins and riveting under pressure of the powder into a solid mass cannot be successfully accomplished with every form of material to become active, but the material

used in the Sperry battery welds up strongly in the press, and, after the chemical formation, becomes hard like soapstone. This active material consists of 80 to 85 per cent. of finely-divided pure lead, obtained by dissolving a precipitation, to which is added 15 to 20 per cent. of lead oxide. These are thoroughly mixed, and to the mass thus formed is added about one-twenty-fifth of a compound of alkaline salts and other ingredients.

The alkaline salts and other ingredients are themselves inert, and their function is twofold:

First. They decompose or dissolve when the plates are subjected to the acid bath, just before being subjected to the electrolytic forming process, leaving numerous minute cells throughout the mass of material upon the plates, which cells permit the electrolyte to thoroughly penetrate the mass of material upon the plates during the time they are subjected to the forming process, and also permit the expansion of this

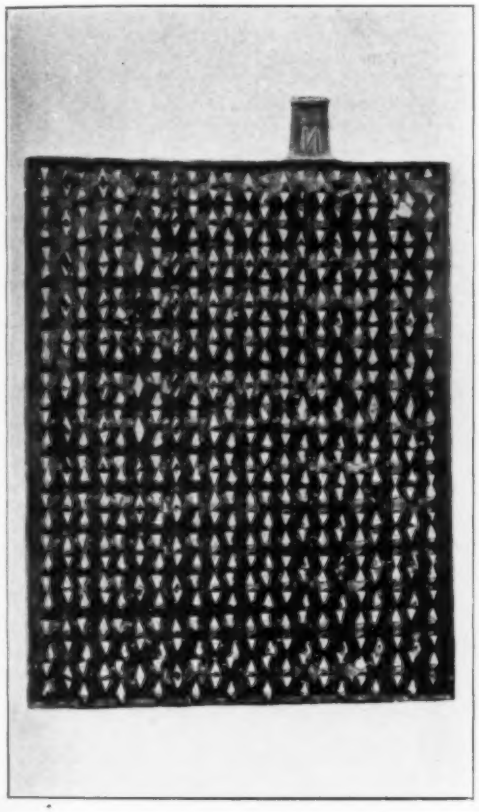


FIG. 1.—GRID, SPERRY BATTERY.

mass of material during the expansion which takes place in the material while the plates are subjected to the forming process, and thereby prevents the active material from crowding off or disintegrating from the grid or support and seriously injuring the plates.

Second. They have the peculiar property of causing the mass of material to harden, not only during the time that the plates are subjected to the forming process, but also during the use of the plates in a storage battery. In other words, this mixture accelerates the forming of the plates by increasing the penetration of the electrolyte, and also prevents serious injury to the plates that otherwise would be caused by the expansion and contraction of the mass of material; and, as above stated, also increases the hardening condition of the mass of material during the use of the plates.

The composition of the active material used, its method of application and the formation of the Sperry battery are such, however, that trouble from disintegration and dropping away of active material is obviated. There are a number of these batteries that have been in use for over two years, and the positive plates are hard, solid and durable.

The corrugation of the grid horizontally allows proper expansion, and relieves the plate of any tendency to buckle. As an additional precaution, however, the Sperry pyroxylin envelope is used, which is applied to the outside of the plate and covers it, passing down one side, under the bottom of the plate, and up the other side. It is evident that if any active material should be loosened by any extraordinary circumstance, it would not be able to drop off the plate, being held in position by the outside coating. If a particle of material should, by any chance, drop off, it is retained in the pyroxylin envelope and will not be able to short-circuit the battery.

FIG. 2.—PYROXYLIN ENVELOPE.

This covering, or pyroxylin envelope (as shown by Fig. 2), is made of open-mesh cotton cloth, such as "cheese cloth," which is chemically treated, forming a cellulose nitrate, which is termed "pyroxylin," and which is of the same general character as gun cotton. The addition of a small quantity of nitrobenzol renders it inert.

The jars in which the elements are placed are of the hard-rubber variety, but different from the usual hard-rubber jars in that they have a series of ribs, capped with soft rubber, extending across the bottom of the cells. On these soft, resilient ribs rest the plates, which are in this way relieved from excessive shock or jar. The separators are corrugated, perforated, ribbed, hard rubber.

Fig. 3 shows a curve of discharge of the Sperry battery taken from 44 cells in series. These cells weigh 1,005 pounds

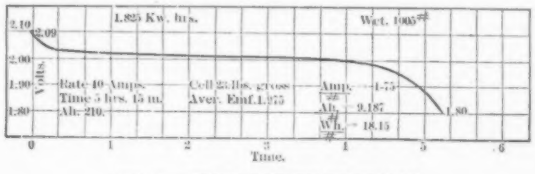


FIG. 3.—SPERRY BATTERY DISCHARGE.

gross, or 23 pounds each. The discharge rate was nearly 40 ampères, and the average voltage 1.975. The curve shows the unusual results of 1.75 ampères, 9.187 ampère hours and 18.15 watt hours per pound gross weight at 5¼-hour discharge, giving, at this rate of discharge, 40 pounds per horse-power hour, corresponding to an energy sufficient to raise its own weight against gravity at sea level about 9 miles.

This is equivalent to 2.65 ampères, 7.95 ampère hours, 5.03 watts and 15.09 watt hours per pound at the three-hour rate. There are several sizes of these cells manufactured, the principal ones being 2 9-10 x 5¾ x 10 inches, and weighing 15 pounds, gross; 2 x 7¼ x 10½ inches, and weighing 18 pounds, gross, and 3 x 7¼ x 10½ inches, weighing 23 pounds.

A great number of life tests have been made on this battery, both in laboratories and on vehicles and in practical work.

One vehicle made 7,770 miles with the batteries at a loss of 28 per cent. of the original capacity when the test was discontinued. Several of the Sperry batteries have been in operation actively for over two years, and showed splendid results. The negative plates were apparently as good as when the battery was made, and a test conducted under the general supervision of Prof. John W. Langley, of the Case School of Applied Science, shows that the battery carried through a uniform rate of discharge of 1 ampère per pound until the carriage had run the equivalent of 3,060 miles. This test shows the capacity of the battery for the last ten discharges to be 10 per cent. in excess of the first ten discharges. The battery had not revealed any indication of falling off in capacity, and the forty-fourth discharge of this battery, taking it at 1 ampère per pound of complete working cell, is a mean potential difference throughout the curve of over 2 volts, namely, 2.014, as shown by the following fifteen-minute readings of potential difference and positive and negative cadmiums:

Time.	Voltage between Plates.	Voltage between Positive Plate and Cadmium.	Voltage between Negative Plate and Cadmium.
12.	2.27	2.37	.13
.15	2.12	2.22	.13
.30	2.12	2.22	.13
.45	2.10	2.20	.13
1.	2.10	2.20	.13
.15	2.10	2.20	.13
.30	2.08	2.19	.13
.45	2.07	2.18	.13
2.	2.05	2.16	.13
.15	2.03	2.15	.13
.30	2.03	2.15	.13
.45	2.03	2.15	.13
3.	2.03	2.15	.13
.15	2.00	2.13	.13
.30	2.00	2.12	.13
.45	1.98	2.10	.13
4.	1.98	2.08	.13
.15	1.97	2.07	.15
.30	1.93	2.03	.15
.45	1.93	2.03	.15
5.	1.90	2.03	.15
.15	1.87	2.02	.16
.30	1.83	2.00	.17
.45	1.80	1.97	.17

The company also manufacture a battery for automobile purposes, known as the "National." This battery is a combination of Sperry negative and Planté positive plates. The negative plates are 3-16 inch in thickness, and the positive plates ¼ inch in thickness. The former are made as explained in the description of the Sperry battery. The latter are made from chemically pure sheet lead, rolled to the desired thickness, cut into strips or ribbons and passed through machines of special design, which knurl and weave a straight and corrugated strip alternately. The ribbons are then placed in a form and subjected to hydraulic pressure, fitting them to the frame or grid, which is cast from an alloy of antimony and lead in

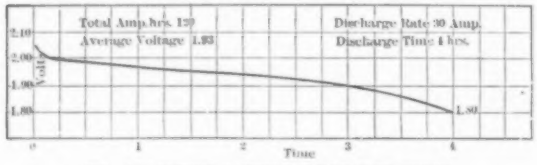


FIG. 4.—SPERRY BATTERY DISCHARGE CURVE.

two pieces. They are next placed in the grid, the center supports and ends of which are burned together, making the plate one piece.

The plates are electrochemically formed by the usual Planté method. Fig. 4 shows the discharge of 24 cells of this battery after 80 discharges, and the battery shows no sign of deterioration. Fig. 5 is the "National" positive plate.

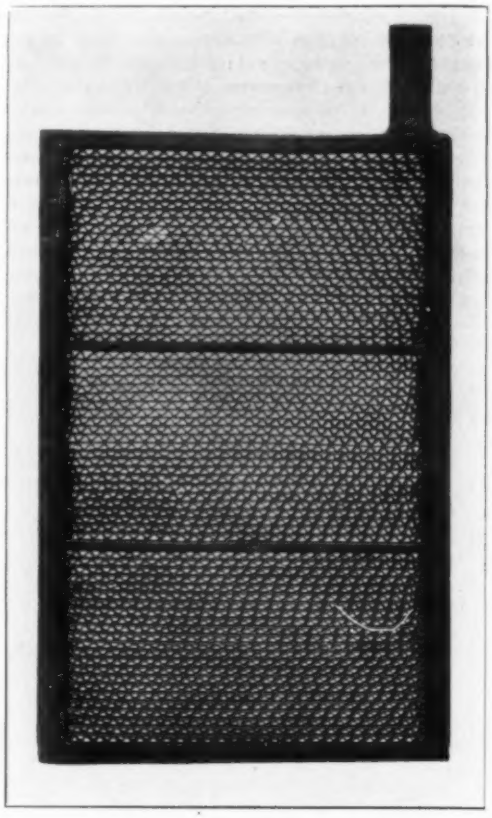


FIG. 5.—NATIONAL POSITIVE PLATE.

The extremely large surface secured by this method of construction makes it possible to obtain the capacity desired with a thin, hard, coherent layer of active material, and permits a free flow of the electrolyte through the plate, allowing it to withstand rapid charging and discharging without serious injury.

WESTERN STORAGE BATTERY.

The more completely the active material covers the conducting plate or grid, the more enduring is the plate, more especially the positive electrode. For this reason the grid used in the Western storage battery, made by the Western Storage Battery Co. for the National Vehicle Co., Indianapolis, Ind., has a conducting diaphragm of thin, perforated lead running through the center of the plate, just midway between the surface of the outer frame of the plate; then, horizontally across this diaphragm are cast thin lines of lead, the outer edges of which are turned down, so that a slight shoulder is made, under which the oxide paste, to become active, is forced by hand pressure, thus confining the paste against outward pressure, which takes place in the process of forming the positive plates. When the plate is thoroughly pasted, small points of lead only show on the surface. Thus the forming process, in which the electrical current tends to follow the more prominent lead as its easiest line of conduction, is forced to seek the main conductor in the center of the plate, passing through the oxide paste to reach it, and producing the necessary chemical changes on its way. This tends to form the electrodes more evenly. The plates made in this way are light, but stiff, and, being cast of an alloy of lead and antimony, are less rapidly decomposed by the constant action of electrolysis in charging and discharging than soft lead would be. A plate, for example,

of a surface area of 4⅞ x 7¾ weighs 11 ounces, and will hold, when properly pasted, about the same weight of lead oxide paste when dry. Seven of these plates, when formed and charged, have a capacity of 68 to 70 ampère hours when discharged at the high rate of 20 ampères per hour.

In order to give more endurance than is usual in a light battery, the positive electrodes are protected from washing, which the motion of the vehicle gives to the battery electrolyte, by a thin pad of spun glass, made for this purpose. It is held against the two surfaces of the positive plate by perforated hard rubber, on one side of which are several perpendicular ribs, about 1-16 inch thick and ⅛ inch high. This gives free circulation of the liquid and gas along the negative plate, and also holds the very resilient glass pad firmly against the positive plate. The combination of spun glass and hard rubber for separators and insulators has proved an improvement, since there is no chemical action in this material, as there would be in any form of wood or cellulose, which chemical action, set up by electrolysis, is always detrimental to the durability of the lead grid. The following data are the results of a test of a 40-cell battery, each cell weighing 14½ pounds, complete. This battery was made up for the National Vehicle Co., for their road wagon, designated in the list as R 2 battery, and consists of seven plates, three positives and four negatives, the plates having each a surface area of 4⅞ x 7¾ inches. The specific gravity of the electrolyte was 1.250 fully charged, and 1.117 at the end of the discharge:

Time.	Ampères.	Volts.
12.	20	82
1.	20	81
1.30	20	80
2.	20	79.5
2.30	20	78.5
3.	20	77
3.30	20	75
3.45	20	68

This gives, for a 3¾-hour discharge, 75 ampère hours, with an average power of, approximately, 1,600 watts. At 68 volts the discharge is cut off and recharging at once commenced, since the drop to 68 volts for the series of 40 cells shows 1.6 volts to each cell, which is as low as any battery could be discharged.

The next size of battery, made for stanhope vehicles and park traps, contains the same number of plates, the surface area of which is 5½ x 8¼ inches, and the discharge rate is 25 ampères, instead of 20, for 3¾ hours, which gives 94 ampère hours. Forty-four of these cells, after making a trip over country roads for three days, of about 65 miles each day, charging in this time three times, made a run of 118 miles the day after charging on the asphalt streets of Indianapolis, taking about eleven hours for the test. In other respects, this battery does not differ outwardly from other batteries in general use.

SMITH STORAGE BATTERY.

The tray storage battery, invented by Malcom O. Smith, and made by the Smith Storage Battery Co., Binghamton, N. Y., differs in its form widely from the batteries made by other manufacturers, although it involves no new principle. The main new point is that the jars are dispensed with, and the lead plates themselves are used for holding the electrolyte. The gridded plates are formed into oblong trays, with pointed bottoms, the ends also receding from the top to the bottom, so as to permit of nesting.

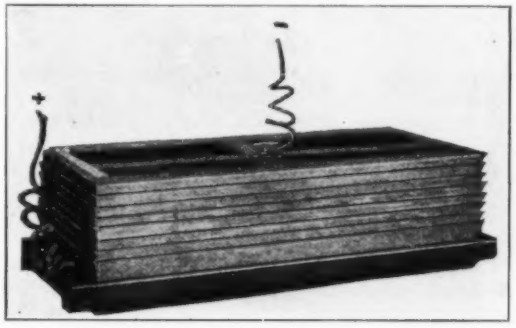
Any desired number of trays can be nested on top of each other, perforated separators of sheets of hard rubber or other suitable material keeping the trays from contact with each other. When nested, there is sufficient space between the trays to hold the electrolyte, which is as much in contact with the bottom of the tray above it as with the under one, which holds it. This permits of an equal chemical action upon the upper surface of one tray and the under side of the one above it.

In preparing the plates, the under side of each tray is chemically treated to become oxide, and the upper side peroxide of lead. This makes the upper side of each tray the positive side, and the under one the negative side, of what in other batteries would be a single cell.

The addition of another tray to the nest is simply the same as adding another cell to an ordinary battery. Of course, the bottom of the lower tray and the inside of the upper one are plain, and are not in contact with the electrolyte. A battery of 11 trays is practically the same as an ordinary one with 10 cells. The voltage of the battery will be twice the number of trays minus one.

One of the battery terminals, the positive, is attached to the bottom side of the bottom tray, and the other, the negative, to the top of the upper one. For the use of the entire battery, there is no connection between the trays except the electrolyte, the use of "jumpers" between the plates, as in ordinary batteries, being unnecessary.

Any combination of series-multiples or multiple series connections can be obtained that are possible with any battery. One terminal can be applied to the top of any tray of the nest, the other to the bottom of any other one. The voltage will always be twice as much as the difference between the number of trays. Between the top of the second tray and the bottom of the fourth one, the e. m. f. is 4 volts; the top of the third and the bottom of the ninth, 12 volts, etc.



SMITH STORAGE BATTERY.

One of the advantages claimed for this type of battery is its extremely low internal resistance. There are no lugs, soldered joints or loose connections, with connecting wires or strips from plate to plate, to offer resistance. At the latter part of a discharge, the current does not have to come from the bottom of the plate through the already discharged upper end. The discharge is practically continuous from the entire surface of every plate.

This results in another advantage, which is the rapid or uneven manner in which it can be discharged without fear of buckling. Inasmuch as the discharge is from the entire surface of all of the plates, it is claimed to make little difference whether it is accomplished in two or three hours or two or three days. Response is made to sudden changes of load with slight variation in voltage. This feature of even response to variable loads is of particular advantage for automobiles, where the demand varies so suddenly.

The form of the battery is claimed to preclude possibility of the deposit of active material to form a short circuit between the plates, as frequently happens with jar batteries; such deposits come from the positive plates. In these batteries the positive face of the tray is up, so that there is no tendency for loosening of material; and, should that happen, it simply rests in the bottom of the tray, where it can cause no trouble.

Dispensing with all jars, either of glass or hard rubber, decreases the weight of the battery considerably, and reduces the cost. It is possible to nest an entire battery of any number of cells up to 20 or more.

[*To be continued.*]

Personal.

Prof. F. Haber sails for Europe on December 13th. On his extended trip through the United States, he visited nearly all the important electrochemical plants of this country. He intends to publish a report in the *Monographieen fuer Angewandte Elektrochemie*. He expects to issue this report in three or four months. In a recent letter to the president of the American Electrochemical Society, Dr. Haber expresses his sincere thanks for the very amiable reception tendered to him, and extends his hearty wishes for the future welfare of the Society.

DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.

DIAPHRAGM CELLS FOR THE PRODUCTION OF CAUSTIC ALKALI.

(*Continued from page 114*)

489,990. October 25, 1892; Henry Blackman, New York, N. Y.

Utilizes difference in specific gravities of brine saturated with chlorine and caustic soda solution, to maintain anode and cathode products of brine separate, by electrolyzing in a centrifugal apparatus, such as a revolving iron drum. Inner surface of drum partially protected by insulating coating, leaving cathode surface at greater distance from axis of drum than are the anodes, which may be arranged in a ring. Separate partitions to direct caustic soda, hydrogen and chlorine to suitable outlets. Central feed pipe for brine. Armature of dynamo to furnish current may be carried on same shaft as centrifugal electrolytic cell.

487,906. December 13, 1892; Thomas Craney, Bay City, Mich.

Closed iron vessel, serving as cathode, containing a number of anode compartments or porous cups. Each cup consists of a number of superposed, loosely interlocking, conical rings of stoneware or glass. A central anode in each cup, also consisting of a series of smaller superposed, conical cups, the space within the cups and the interstices between them being filled with pulverized carbon. Space between anode and porous cup filled with salt crystals, which gradually dissolve and replenish the solution.

488,708. December 27, 1892; Thomas Craney, Bay City, Mich.

Long anode and cathode compartments side by side, partially separated by a depending partition. A layer of sand or asbestos on the bottom of both compartments extends up above lower edge of the partition. A row of anodes, each consisting of a cup filled with pulverized carbon and resting on the sand layer. Connection to the carbon in each cup made by a tube filled with carbon. Cathode compartment divided longitudinally by a series of transverse vertical cathode plates, serving as baffles, causing movement of solution in a vertical zig-zag from end to end. Resistance between each anode and main electrical conductor arranged to increase current supply from inlet to outlet of cell.

489,677. January 10, 1893; James Greenwood, London, Eng.

Vessel of copper, lined with carbon or iron, serving as cathode. Anode, parallel plates of retort carbon, tinned on adjacent faces, with type metal cast between. Diaphragm, superposed V-shaped troughs of porcelain or glass, separated by asbestos or powdered steatite. Upward circulation of brine in both compartments. Anode and cathode solutions may flow through a number of cells in series.

491,700. February 14, 1893; Elisha B. Cutten, New York, N. Y.

Apparatus similar to that of 480,491, except that a porous cup may be substituted for glass anode bell. Upper and lower ends of porous cup glazed. Circulates strong brine upward along anode.

496,863. May 9, 1893; Thomas Craney, Bay City, Mich.

Apparatus similar to that of 487,996. Tank suspended from above and has conical bottom, delivering to a receiver below. Automatic device, controlled by strength of caustic, to regulate outflow from receiver.

496,864. May 9, 1893; Thomas Craney, Bay City, Mich.

Apparatus similar to that of 488,708. Modification shown employing a row of anode bells dipping into a layer of sand, with a cathode between each pair of bells.

496,865. May 9, 1893; Thomas Craney, Bay City, Mich.

Vessel partially divided into anode and cathode compartments by a depending partition. Sand layer on bottom extends up above lower edge of partition. Anode, solid or powdered carbon resting on sand at base of anode compartment. Anode conductor, a tube perforated at its upper end and filled with carbon. Cathode, a loosely-rolled sheet of metal.

498,768, 498,769, 498,770. June 6, 1893; Thomas Craney, Bay City, Mich.

A row of cells similar to that of 496,865, with all the anode and all the cathode compartments connected in series. Cells may be arranged in steps.

498,771. June 6, 1893; Thomas Craney, Bay City, Mich.

Porous cup, consisting of concentric perforated cups, with an intermediate space filled with asbestos. Inner cup filled with granular carbon, serving as anode.

501,121. July 11, 1893; Charles N. Waite, Newton, Mass.

Purifies brine by adding a soluble barium salt, preferably chloride, to remove sulphuric acid existing in combination with calcium, magnesium or sodium.

501,628. July 18, 1893; James Charles Richardson, London, England.

Cathode, a horizontal endless belt of sheet metal, supported on rollers near the bottom of vessel. Terminal brush bears on cathode. Feeds a depolarizer, such as copper oxide, onto one end of the cathode, and delivers the spent depolarizer from the other end into a receptacle, from which it is elevated. Anode bell arranged with its lower edge in contact with layer of depolarizer on cathode.

504,774. September 12, 1893; Thomas Craney, Bay City, Mich.

Separate anode and cathode compartments, connected by an inverted U-tube filled with asbestos. Anode and cathode similar to those of 496,865. Fills cathode compartment with water or weak brine, and displaces caustic by adding fresh water.

505,895. October 3, 1893; Elisha B. Butten, New York, N. Y.

Apparatus similar to that of 480,491 and 491,700. Automatic devices for supplying saturated brine and withdrawing caustic.

507,886. October 31, 1893; Thomas Craney, Bay City, Mich.

Separate, parallel, rectangular anode and cathode compartments of iron. Anode compartment protected by coating of asphalt and an inner lining of cement. A series of inverted U-tubes connect the compartments. End of each U-tube in anode compartment may rest on a pile of asbestos sheets. An air exhaust pipe leads from the bend of each U-tube. Anode, a layer of pulverized carbon resting on bottom of compartment, with a series of connections, each a carbon pencil encased in earthenware or cement. May have an anode compartment along each side of cathode compartment.

[*To be continued.*]